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DISTRIBUTION AND BIOTIC EFFECTS OF NUTRIENTS IN FLATHEAD LAKE, MONTANA

MONTANA UNIVERSITY

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ENVIRONMENTAL PROTECTION AGENCY

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DISTRIBUTION AND BIOTIC EFFECTS OF NUTRIENTS IN FLATHEAD LAKE, MONTANA

A Report on Research Work Done in
1973-1975 with the Support of the
Environmental Protection Agency and
the State of Montana Department of
Health and Environmental Sciences.

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January 1975

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FLATHEAD LAKE NUTRIENT STUDY*

SUMMARY AND CONCLUSIONS

Phosphorus concentrations reported in this study are about 1/10 of previously reported values. Sensitivity limits of the phosphorus methods used in this study (0.01 mg/l P) were not low enough to accurately determine phosphorus concentrations in the drainage. Nevertheless, low phosphorus concentrations were shown to be important in controlling phytoplankton production. Nitrogen concentrations did not affect phytoplankton production. Although phosphorus inputs to the lake are sufficient to support nuisance pelagic blooms of algae, such blooms did not occur. The best estimate of these inputs are 1,400 and 100 pounds per day from the Flathead and Swan Rivers, respectively. High concentrations of iron plus constantly oxygenated water and/or large suspended sediment inputs are apparently responsible for the lack of blooms. Either or both of these factors may physically remove phosphorus from the lake's photic zone. In addition, the suspended sediments decrease light penetration and may actually precipitate algae. Because of these factors, it is impossible to estimate the amount of phosphorus the lake can annually assimilate before changes occur in algal species composition and production. Because of the importance of suspended sediments to the present lake ecosystem, it is imperative that any factors which may change suspended sediment inputs to the lake be controlled.

Water Quality Bureau data not included in this report indicate the following contributions to the lake from sewage treatment plants in pounds per day: Kalispell - 105; Whitefish - 42; Columbia Falls - 11; Bigfork - 6. Thus, the total phosphorus contributed to the lake by sewage treatment plants (162 pounds per day) is about 11% of the total. Because of these relatively minor contributions from the sewage treatment plants and the uncertainty of the assimilative capacity of the lake, phosphorus removal at the sewage treatment plants in the Flathead drainage is not desirable at this time. However, because the lake is not limited by nitrogen and because the population in the drainage is increasing, the feasibility of phosphorus removal should be determined for existing and planned sewage treatment plants.

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The study was undertaken to describe seasonal dynamics of various physical and chemical parameters involved in plankton community metabolism and to relate findings to nutrient loading trends previously reported. The importance of various chemical parameters, especially phosphorous and nitrogen, to standing crop dynamics of net phytoplankton was evaluated in relation to physical parameters such as light, turbidity, circulation, and temperature. The major objective was compilation of baseline data and clarification of basic hydrodynamics so that the limnology of Flathead Lake might finally progress from a formative beginning to a status providing capability for informed management.

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INTRODUCTION

Flathead Lake and the Flathead Drainage have drawn nationwide public attention in recent years. The region has long been famed for its natural beauty and the quality of its environment; these considerations have made the Flathead desireable to land speculators and subdividers among others. Changes in land use, increased areas of lands used exploitively and increasing affects on the environment by ever larger resident and tourist populations have begun to cause concern for the future of the drainage.

It is seen, as well, that in the future the lake and its drainage will require sound management based on real information concerning changes in the environment which have happened in the past, which are occurring at present, and which may be desireable or tolerated in the future.

A number of state and federal agencies have undertaken studies of various aspects of importance to management of land use and water quality in the drainage. A few recent studies deserve note: Cunningham and Werth, 1973; University of Montana School of Forestry, 1974; Reynolds, 1974. Other earlier studies are reviewed in the compilation by Seastedt and Tibbs, 1974.

Settlement in the region by European man occurred late in the 19th. Century. Prior to the 1820's the land was wilderness and belonged to Indians of the Salish Tribal Nation. The rate of settlement was slow but steady, and was enhanced by the coming of the Great Northern Railroad in 1891. Lumber was, and remains, a principle industry of the area. The Stillwater, Whitefish, Flathead and Swan Rivers served as transport systems for the earliest lumber center, Somers, located on the northwest shore of Flathead Lake.

Flathead Lake served as a transport system from Polson to points north until a road was built along the west side of the lake. Steamboats carried passengers and cargo to points along the lake and upper Flathead River.

The Flathead River system remained largely unmodified until the construction of Kerr Dam below Polson in 1938. The dam regulates the upper ten feet of Flathead Lake and has a capacity of 1,219,000 acre-feet (Montana Water Resources Board, 1968).

The Flathead drainage system was significantly modified by the Hungry Horse Reservoir. This dam began operation in 1953 on the South Fork of the Flathead River; the dam has a capacity of 3,468,000 acre-feet (ibid). The dam regulates much of the spring run-off on the South Fork, reducing the flow of the Flathead River during this period. Conversely, the dam discharges water during other periods of the year, correspondingly increasing the volume of the Flathead River.

The geological processes which have resulted in the present rugged terrain of the Flathead drainage have been discussed by many investigators; current reviews can be found in Silverman (1971) and Johns (1970). Fields (1971) is a useful source book on the geology of the region.

Two major occurrences have been responsible for present land structure. The first and most significant event, was the great crustal deformation that occurred in the Late Cretaceous Period, and which is responsible for the mountain formation in the area. Pre-Cambrian sediments predominantly Ravalli quartzite and Peigan limestones compose much of the present mountain formations. The second factor responsible for much of the present land conditions, lakes and drainages, was the massive glaciation, especially the last glacial advance of the late Wisconsin age. The moraines left by this last ice movement are directly responsible for the formation of Lake Mary Ronan and Flathead Lake's present configuration (Smith, 1966).

Konizeski (1968), reports that Whitefish Lake is also of similar origin. He further states that the Flathead arm of Glacial Lake Missoula innundated the entire Kalispell Valley to an altitude of 4,200 feet. Sand, silt, and clay accumulated in the glacial lake to a thickness of several hundred feet and covered older deposits, (Konizeski, 1968). These lacustrine deposits, then, along with numerous moraines and glacial debris, compose much of the subsoils in the lower areas (below 3,400 feet). Konizeski found that Tertiary and Quaternary deposits were as much as 4,800 feet deep in the Kalispell Valley.

Soils formations in the Flathead drainage have had only about 12,000 years to form. Before that the glaciers had removed pre-existing soils. Soils are usually thin except where there are aluvial, lacustrine or aeolian deposits of silt, sand, or clay.

A brief review of the fauna and flora of the region is given in Seastedt and Tibbs (1974). Also discussed at some length therein are climatological and population data, and the effects that increasing populations and attendant increases of rural and domestic sewage may have on lakes in the Flathead drainage. In their study of the land use and water quality of the Flathead Drainage, Seastedt and Tibbs (1974) discuss water quality studies on streams and tributaries of Flathead Lake, chemical constituents of natural waters in the Drainage as known to the time of that report, and with that information and estimated projections based on waste water, farming practices, forest management and other land uses, attempted to assess nutrient loading in Flathead Lake. It will be seen below that those 1974 estimates were high.

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THE PRESENT STUDY

Limnological investigations of Flathead Lake began around 1890 (Forbes, 1893). The physical and biotic processes involved in controlling primary production of Flathead Lake are nevertheless poorly understood. Previous studies (Potter and Baker, 1961; Morgan 1968, 1971) have reported high phosphorous and nitrogen values in the photic (photosynthetic) zone (Table 1). According to these data, the Lake should support heavy biomass or green algae or perhaps bluegreen algae instead of the observed low densities of phytoplankton organisms which are primarily diatoms. Lake hydrodynamics, however, or low concentrations of some other nutrients may be responsible for the present apparent oligotrophic nature of Flathead Lake (G. W. Prescott, personal communications).

Seastedt and Tibbs (1974) have suggested that dissolved solid concentration is increasing in tributary rivers primarily due to cultural activities in the drainage basins. Area land planning and management reports have emphasized maintenance of high water quality standards as prerequisite to preserving the high quality of Flathead Lake (Seastedt and Tibbs, 1974; Dils, et al., 1973).

The present study was undertaken to describe seasonal dynamics of various physical and chemical parameters involved in plankton community metabolism and to relate findings to nutrient loading trends previously reported. The importance of various chemical parameters, especially phosphorous and nitrogen, to standing crop dynamics of net phytoplankton was evaluated in relation to physical parameters such as light, turbidity, circulation, and temperature. The major objective was compilation of baseline data and clarification of basic hydrodynamics so that the limnology of Flathead Lake might finally progress from a formative beginning to a status providing capability for informed management.

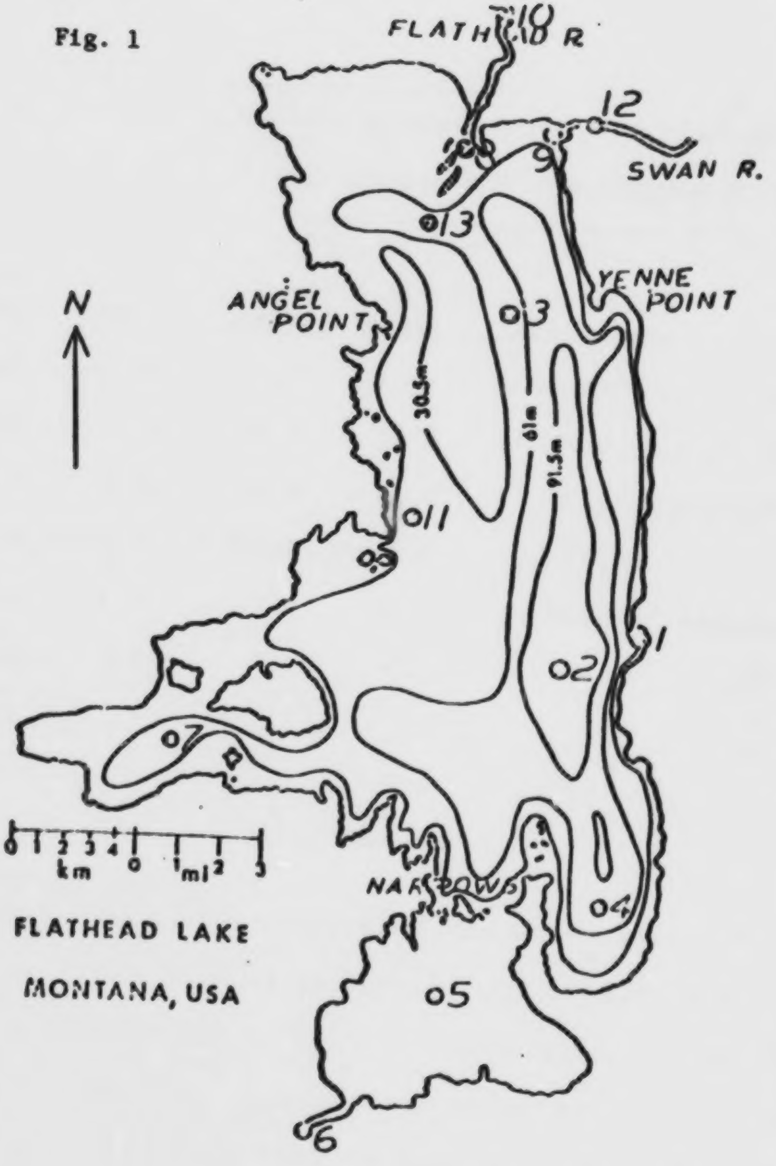
Table 1. Summary of selected Flathead Lake water chemistry as reported by previous investigators. All data in mg/L^{-1}

	Potter and Baker, 1961	Morgan 1967	Morgan 1968	Morgan 1969	Ivory 1971-72
Alkalinity	89.7	90.0	87.5	80.0	83.8
Total Iron	0.60	0.10	0.05	0.05	0.02
Nitrate-Nitrogen	0.05	0.16	0.12	0.19	0.06
pH	8.0	8.3-7.8	8.2-8.7	9.3-8.8	8.0-8.4
Ortho-Phosphate	0.20	0.16	0.11	0.15	0.035
Silica (SiO_2)	-	5.0	4.7	4.5	4.6

THE STUDY AREA

In discussing preliminary observations on factors influencing plankton communities in Flathead Lake, Potter and Stanford (1974) described the geology, history, and general morphology of the Lake and its drainage basins; only pertinent information is repeated here. Flathead Lake is located in northwestern Montana in the upper Flathead River drainage. Most inflowing water is received at the Lake's north end via the Flathead and Swan Rivers (Fig. 1) although there are numerous small streams entering along the west and, especially, the east shore, their combined volume is insignificant

Fig. 1


10
FLATHEAD R
12
SWAN R.
9
13
ANGEL POINT
YENNE POINT
3
N
30.5m
61m
91.5m
11
8
1
2
7
0 1 2 3 4 km
0 1 mi 2 3
4
NARROWS
5
6
FLATHEAD LAKE
MONTANA, USA

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in comparison to that recruited from the 7,000 acre drainage area of the two tributary rivers. Average flow of the Flathead and Swan Rivers is 9,774 and 1,159 cfs respectively. The outlet is at the southern end of the Lake where the upper 3 vertical meters of Lake level is controlled by discharges from Kerr Dam for power generation. Morphological features of Flathead Lake are summarized in Table 2. Bottom contours are being mapped in detail, but are not yet available (C.A. Silverman, personal communication); however, the eastern half of the Lake averages about twice as deep as the western half (Fig. 1). A deep trench, attaining depths of 100 meters or more in places, extends south along the east shore from Yenne Point to the Narrows and Skidoo Bay. The northeastern area of the Lake is rather uniformly shallow (10-30M) due to deposition of sediments by the Flathead River. The flow of the river is thought to extend generally along the western shoreline, deflected toward the center somewhat by Angel Point. The Swan River flows through large Swan Lake and a small hydroelectric impoundment just before entering Flathead Lake; these function as sediment sinks and, therefore, except during those years of highest runoff, the River is always very clear and contributes very little sediment to the Lake.

Table 2. Morphological features of Flathead Lake, Montana from (Potter and Stanford, 1974).

Maximum length	45.5 Km
Mean breadth	10.5 Km
Maximum depth	110.3 m
Mean depth	13.5 m
Area	475.6 Km^2
Area of islands	14.3 Km^2

Table 2. (continued)

Volume	24.9 Km^3
Length of shoreline	301.9 Km
Shoreline development	3.9
Insularity	3.0%
Mean Retention Time of water	2.37 years

All of Polson Bay is less than 6m deep, but a surprising dropoff of 60-80 meters occurs only 100 meters or so north of the Narrows area.

The long fetch of the lake's valley allows strong winds which keep the lake surface rough much of the time, especially in winter. This characteristic surface turbulence and the Lake's great volume work together to keep the lake from freezing over for appreciable lengths of time. Ice pack lake-wide occurs only once in every four to seven years, usually in March (D. Hanzel, personal communication). The Lake is a clear blue during fall and winter but turns greenish-brown as the amounts of seston increase in spring, primarily due to clay turbidity from Flathead River discharge. The water is again quite clear by mid- to late summer as turbidity settles.

In this study, thirteen sampling stations were established, ten on the Lake and one each on inflowing and outflowing rivers (Fig. 1). The location of each stations was as follows (station names underlined):

1. in middle of Yellow Bay; maximum depth, 27 m.
2. over deepest point in Lake, roughly midway between Yellow Bay and Wildhorse Island and referred to as Midlake station; maximum depth, 110 m.
3. in middle of Lake between Yenne Point on the east shore and Angel Point on the west shore; maximum depth, 60 m.

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4. in middle of Skidoo Bay; maximum depth, 60 m.
5. in Polson Bay midway between the Narrows and the outflow; maximum depth, 6 m.
6. in outflow area of Flathead River at Polson; maximum depth, 5 m; flowing water.
7. in middle of Big Arm Bay; maximum depth, 35 m.
8. at Mouth of Flathead River; maximum depth 10 m, often flowing water.
9. in middle of Bigfork Bay; maximum depth, 3 m.
10. Flathead River at Holt Bridge; maximum depth, 8 m; flowing water.
11. about 200 m from Painted Rocks on the Lake's west shore; maximum depth, 50 m.
12. Swan River at bridge in town of Bigfork; maximum depth, 2 m; flowing water.
13. midway between mouth of Flathead River and Angel Point on Lake's North End; maximum depth, 30 m.

Stations 8 and 9 were inaccessible during low water periods of late winter and early spring. The Flathead River above the Lake meanders and when lake level is maxium, water is backed several kilometers up the river channel. Flow intensity and depth varies seasonally at station 10. Some additional sampling was done in various tributary creeks and at intermediate stations on the Lake during spring runoff.

MATERIALS AND METHODS

Phytoplankton Standing Crop.

Net phytoplankton was quantified at least monthly, weather permitting, at Stations 1, 2, 3, 4, 5, 7, 11, and 13. Samples were obtained at 5 meter intervals from surface to 40 meter level (or bottom) using a 3 liter Van Dorn water bottle. All 3 liters were filtered through a No. 20 mesh plankton bucket to concentrate plankton; samples were preserved immediately with formalin. Algae were enumerated in a one ml Sedgewick-Rafter cell using the method of Welch (1948, pg 286). Dr. G.W. Prescott (U. Montana Biological Station) and Dr. Forest M. Begres (Eastern Michigan U.) kindly verified taxonomic identifications.

Chemical Analysis of Dissolved Solids

Water samples were obtained as often as possible for chemical analysis from 1m and 40 m at deep water stations, or from 1 m and 20 m or less at shallower stations with the same Van Dorn water bottle. Occasionally samples were obtained from intermediate or greater depths. All samples were analyzed for alkalinity, hardness, (Mg. Ca, and total) silica, carbon dioxide, and pH content immediately after collection. These analyses were conducted at the Biological Station laboratory at Yellow Bay. Duplicate samples were cooled and shipped by bus to the Montana State Department of Health and Environmental Sciences laboratory in Helena for analysis of total phosphorous, ortho-phosphate (PO_4) and nitrate (NO_3) content. Monthly samples from same depths were filtered through 0.45 micron aperture Millipore filters, then preserved with concentrated nitric acid (1 ml per 100 ml water) and sent to the Helena laboratory for trace analysis of total iron, zinc and copper. Occasional samples were sent for analysis of cadmium, cobalt, total Kjeldahl nitrogen, and total carbon. The chemical methodology used and threshold level of detection for each parameter is summarized in table 3. One set of midlake samples was sent to the Institute of Water Research laboratory at Michigan State University for analytical quality check.

Algal Assay and Experimental Nutrient Additions

Algal assays using the Selenastrum bottle test (EPA, 1971) were utilized to elucidate limiting nutrients in Flathead Lake. Water samples were obtained from either Yellow Bay or from Midlake stations and immediately shipped to Helena for assay. Experimental in situ additions of phosphorous as $NaH_2PO_4 \cdot H_2O$ were undertaken using cylindrical polyethelene bags after the method described by Shindler (1971). The bags were 1m wide by 10m long and suspended from a wooden frame near shore in Yellow Bay. The bags were filled by divers carrying the open ends through the water column. Nutrients were added as frozen solutions which were allowed to thaw at various depths within bags. Net phytoplankton and chemical water samples were obtained as above prior to nutrient addition and again after a week's time. Changes in net phytoplankton number and species composition and chemical differences were recorded. Several experiments were attempted during May and June, 1974, but only 2 were successful due to problems of maintaining the bags' vertical position in the water column during wind storms. Experimental conditions of the successful attempts are summarized with results.

Table 3. Methods used and minimum detectable concentrations of various parameters monitored. Unless an electronic probe was sued, methods are those given in Taras, et al. (1973).

PARAMETER	METHOD	MIN. DETECT. CONC'N.
Total P	Persulfate Digestion to PO_4	-
PO_4	Stannous Chloride Reduction	30μg/l $(PO_4$-$P)$
Total N	Kjeldahl Digestion	-
NO_3	Phenoldisulfonic Acid Reduction	10μg/l $(NO_3$-$N)$

Table 3. (continued)

PARAMETER	METHOD	MIN. DETECT. CONC'N.
Fe, Co, Zn, Cu	Atomic Absorption (Perkin-Elmer)	10μg/1
Total Carbon	Co_2 Analyzer (Beckman, Model 914)	0.5mg/1
Silica	Molybdosilicate Reduction	0.4 mg/1
Alkalinity	Brom-cresol Methyl Red Titration	
Hardness	EDTA Titration	
Carbon Dioxide (Free)	Methyl Orange Titration	0.5 mg/1
pH	Leeds-Northrup, Hydrolab Surveyor 5	-
Dissolved Oxygen	Hydrolab Surveyor 5	-
Conductivity	"	-
Redox	"	-

In situ Chemical, Thermal, Light, and Turbidity Profiles

Depth profiles to 100 m of temperature, dissolved oxygen, pH, conductivity and oxidation-reduction potential were obtained as often as wind conditions would allow at all stations using a Hydrolab "Surveyor-5" in situ apparatus. For logistical reasons special effort was made to obtain these data at Stations 1, 2, 4, and 13 at least monthly. Data on light were gathered using a secchi disk and a Kahlsico submarine photometer. Levels of light extinction were of most interest. Turbidity was studied intensively during the spring runoff period of April-July, 1974. A Kahlsico turbidimeter deployed by an electrical winch on deck was used to measure relative transparency of water at various depths to 60m.

RESULTS

Preliminary data were gathered during July and August, 1973, but the major research effort encompassed a sampling period from 15 September, 1973, to 20 September, 1974. Sampling was hindered or impossible on some occasions due to wind and rough water. Inclement weather was responsible for some inconsistency in the sampling schedule reported herein.

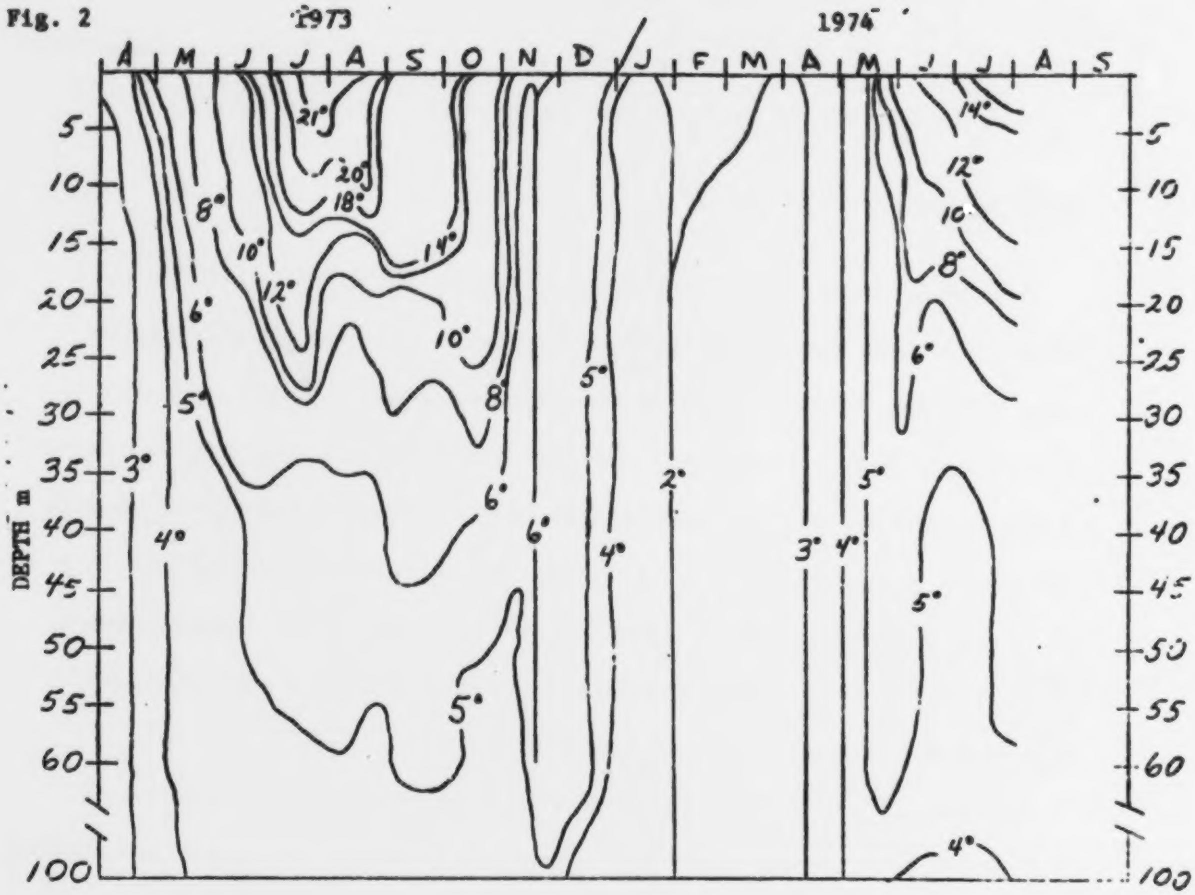
Thermal Regime

Seasonal dynamics in thermal character of the water column at the Midlake stations are illustrated in Figure 2. Thermal stratification began in early summer, 1972; the thermocline gradually sank, the water mass turning over in November. Winter stratification was weak due to wind circulation; the Lake was essentially homeothermos at 2.2° ± 0.2° C from late January to early April. A thermal circulation began again in late April and May and it was followed by construction of the summer thermocline in June, 1974. Flathead Lake is clearly dimictic with spring and fall mixing periods throughout the water column.

Data supplied by Delano Hanzel of the Montana State Department of Fish and Game (Personal Comm.) demonstrated that the 1973 and 1974 summer isotherms were very unstable. Variations of up to 3° were recorded by towing a recording thermister for some distance (approx. 100m) at a constant depth. Thermal conditions were most constant throughout the water column on daily or weekly bases during winter and spring, 1974.

Conditions given in Figure 2 prevailed at all stations with some variation at the more shallow stations. Modification of the thermal regime by river discharge was observed at stations 8, 9, and 13. Polson Bay was homeothermos at surface temperatures throughout the study except on rare

Fig. 2


1973
1974
A M J J A S O N D J F M A M J J A S
DEPTH m
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3°
4°
5°
6°
8°
10°
12°
14°
18°
20°
21°
10°
8
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5°
6°
5°
4°
2°
3°
4°
5°
14°
12°
10
8°
6°
5°
4°

calm days in Spring and Summer. Thermal regimes were not carefully monitored at river stations. The seasonal thermal cycle in the Flathead River above the lake was probably very similar to that reported during 1972-72 by Stanford (1974).

Turbidity and Light Penetration

Depth of light penetration in Flathead Lake was dramatically affected seasonally by varying climatic and biotic processes. Secchi disk and submarine photometer readings were affected by the density of seston in the water column. A secchi disk reading of 14.3 m (47 ft) was observed at Midlake station in November, 1973; incident light was recorded as deep as 55 m. Thus, the Lake appeared deep blue in color due to backscattering blue wave lengths of the visable light spectrum. Seemingly continuous winter cloud cover and surface turbulence reduced secchi disk readings to around 10 m, but the clarity of the water was not changed much as light penetration was routinely recorded to 45-50m in deeper areas of the lake.

Springtime growth of phytoplankton, discussed in detail below, further reduced light availability, but turbidity resulting from upstream snow melt in May and June severely limited light penetration. Secchi disk readings were less than one meter and light became extinguished at 23 m in the Lake's pelagic region and at lesser depths in littoral areas near the mouth of the Flathead River.

Flooding due to spring snow-melt is an annual occurance in the upper Flathead River drainage. Subsoils are predominantly montmorillanite and kaolinite clays; erosion of these clays by tributary streams during periods of rapid snow-melt results in heavy sediment loading in the Flathead River. Bank erosion by the River itself contributes large amounts of suspended solids. The Flathead River discharge into Flathead Lake is therefore typically very turbid during spring runoff.

The 1973-4 winter snowfall in the upper Flathead River drainage surpassed all records. A brief pulse of turbid runoff began in April as large amounts of snow at lower altitudes melted; the major spring discharges, however, began in late May and continued until late June. This prolonged runoff provided an excellent opportunity to document development of clay turbidity in Flathead Lake.

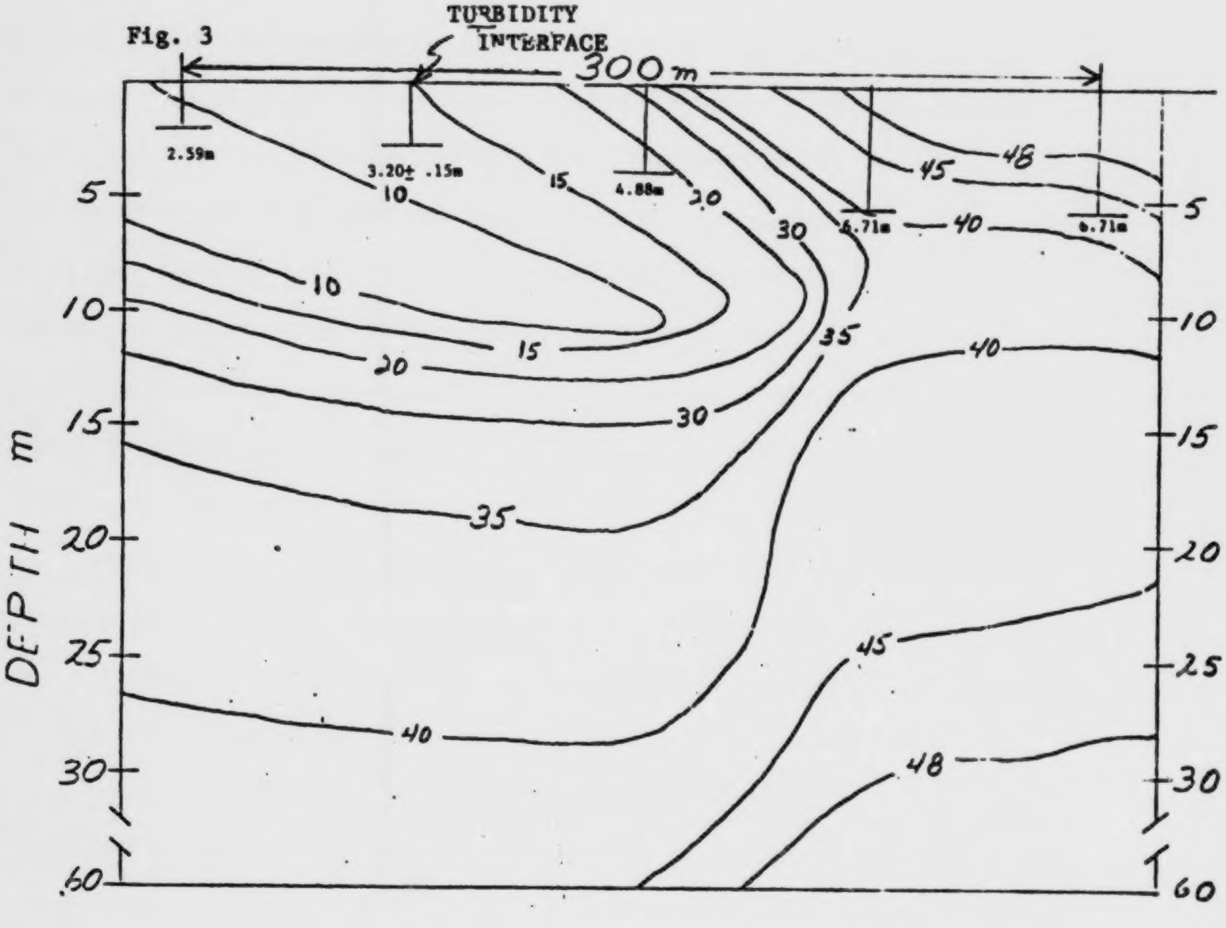
The extreme north end of the Lake became turbid due to the late April pulse of high discharge. Patches of turbid water were observed as far south on the Lake as Yenne Point. This early pulse receded by early May allowing the limited turbid area at the north end to clear up noticeably.

Major turbid discharge by the Flathead River began on 28 May as warm weather prevailed. The River rapidly approached flood stage, discharging 30-50,000 cfs during the first week of June. Peak flow was recorded on 8 June; thereafter the flow of the River began to recede and to clear slowly. The Swan River also delivered heavy runoff to Swan Lake and by 10 June turbid water was passed completely through Swan Lake and on downstream to Flathead Lake. The Swan River discharge to Flathead Lake was decidedly less turbid, however, than the Flathead River effluent.

A large turbidity plume was immediately evident as discharge from the Flathead River increased. Aerial and surface reconnaissance of plume development was undertaken. Turbid river water and clear lake water strongly resisted mixing; interface areas were easily observed on the leading edge of the plume. Logs and other debris accumulated at the interface zone, apparently held there by downward movements of density currents. This mixing resistance caused the warmer turbid water to slide out over colder, clear water. This phenomenon was documented on 7 June when the plume had reached a point midway between station 2 (Midlake) and 3 (Yenne Point). Turbidity-depth profiles obtained in the plume, at the interface, and in clear water south of the plume are summarized in Figure 3. The 15 per cent transmission contour roughly corresponds to the interface area. It was seen that there was no tendency for turbid river water to flow under clear lake water and maintain continuity through the lake basin as has been reported in some deep reservoirs (Ruttner, 1966). Similar observations were made at other areas on the lake. Progressive movements of the plume across the lake surface are illustrated in Figure 4. Flathead River water was discharged directly toward Angel Point along the west shore. Mixing resistance slowed movement of the sediment into the cold, deep water of the eastern half of the Lake. Therefore interface areas were always observed extending southwesterly across the lake. Because of the current pattern, the Midlake station and Yellow Bay were the last areas to become turbid. By 11 June turbid water reached the Narrows and moved into Polson Bay. The constriction in the Narrows caused the plume to spill into Skidoo Bay and move back up the east shore. By 18 June backwelling turbidity joined the trailing edge of the plume and the entire Lake appeared turbid. At all times light transmission was more restricted at the northern and western shores than it was on the eastern shore areas.

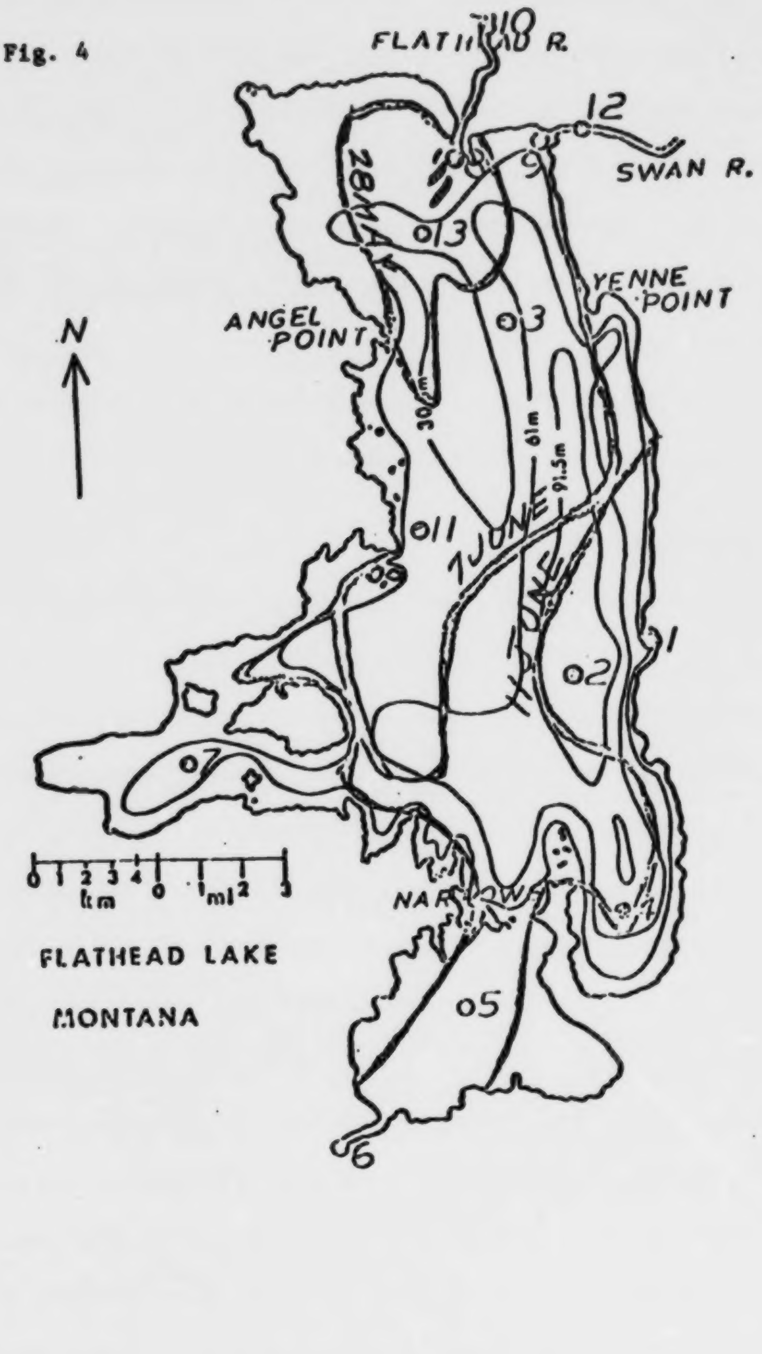
The affect of turbidity on the clarity of the water column was best documented at the Midlake station (Figure 5). Intense turbidity moved in at the surface on 18 July. The water column cleared slowly as clay particles

Fig. 3


TURBIDITY INTERFACE
300 m
2.59m
3.20± .15m
4.88m
6.71m
6.71m
10
15
20
30
45
48
10
40
30
10
15
20
30
35
40
35
40
45
48
DEPTH m
5
10
15
20
25
30
60
5
10
15
20
25
30
60

)

Fig. 4


10
FLATHEAD R.
12
SWAN R.
9
28 MAY
13
YENNE POINT
3
ANGEL POINT
N
30m
61m
91.5m
11
1 JUNE
9
1 JUNE
1
2
7
0 1 2 3 4 km 0 1 2 3 mi
NARROWS
5
6
FLATHEAD LAKE
MONTANA

were dispersed or settled to the lake bottom. On 18 August the upper 60 meters (instrument cables were only 60 meters long) was dramatically transparent, and almost devoid of seston. A secchi disk reading of 13.1 m was recorded on 18 September. Similar turbidity regimes were recorded at other stations. Turbidity contours were extremely unstable and similar to the situation described for the isotherms above. Although sediment traps were not utilized, the sedimentation rate must have been greater in more turbid areas along west shore. In general, however, clearing of surface waters was evident over all of the lake by early August. By mid-August the Lake was again blue in color.

Secchi disk and light data are summarized in relation to phytoplankton dynamics at various stations in Figures 6 through 11.

Net Phytoplankton

Seasonal dynamics in standing crop of net phytoplankton followed patterns previously reported (Morgan 1968, 1971). Total phytoplankton counts were, however, much higher. Bacillariophyceae were always the most numerous net plankters. Total net phytoplankton counts were less than 50×10^3 per liter in fall and until midwinter; however, by February counts began to increase, later reaching more than 800×10^3 per liter during the spring circulation period in April. Counts decreased in May and were reduced even below fall and winter numbers when turbidity moved over the Lake in June and July.

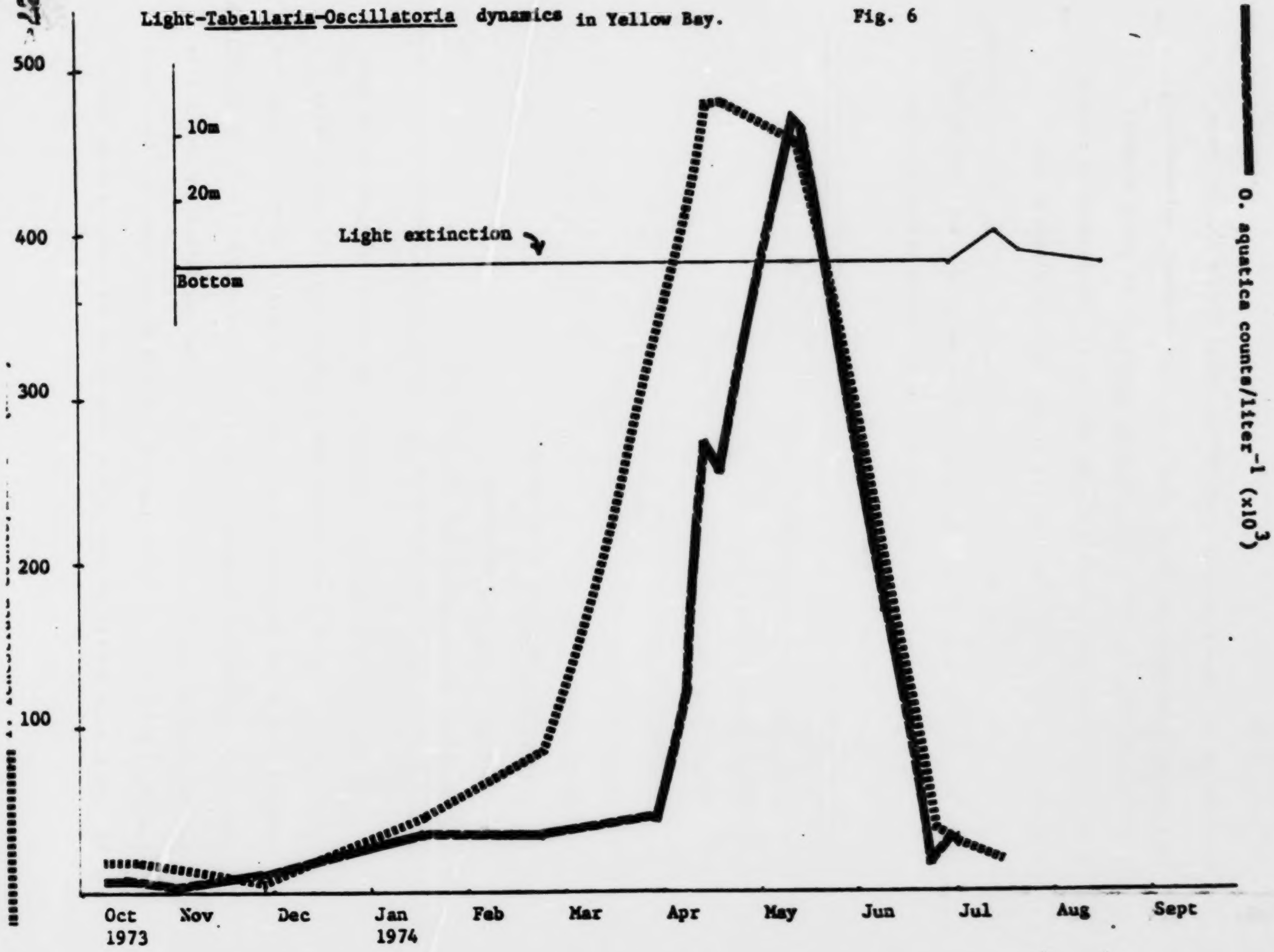
Gaufin (1974) has listed nearly 600 phytoplankton species (identifications verified by Drs. G. W. Prescott and Ruth Patrick) as representatives of the indigenous flora in Flathead Lake. Only a few of these species, however have been reported to be abundant in previous studies (Morgan, 1968, 1971; Moghadam, 1969; Ivory, 1973). We found only nine species to have specimens present in our samples in numbers greater than 500 per liter (Table 4). Of these *Tabellaria fenestrata* was almost always the most abundant, out-numbering other net plankters 4 to 1. *Oscillatoria aquatica* were quite abundant during the spring phytoplankton bloom; this small, filamentous blue-green alga has not previously been reported in the flora of Flathead Lake.

Table 4. Species list of net phytoplankters enumerated. They are listed as they most commonly occurred, in decreasing order, with the most abundant at the top.

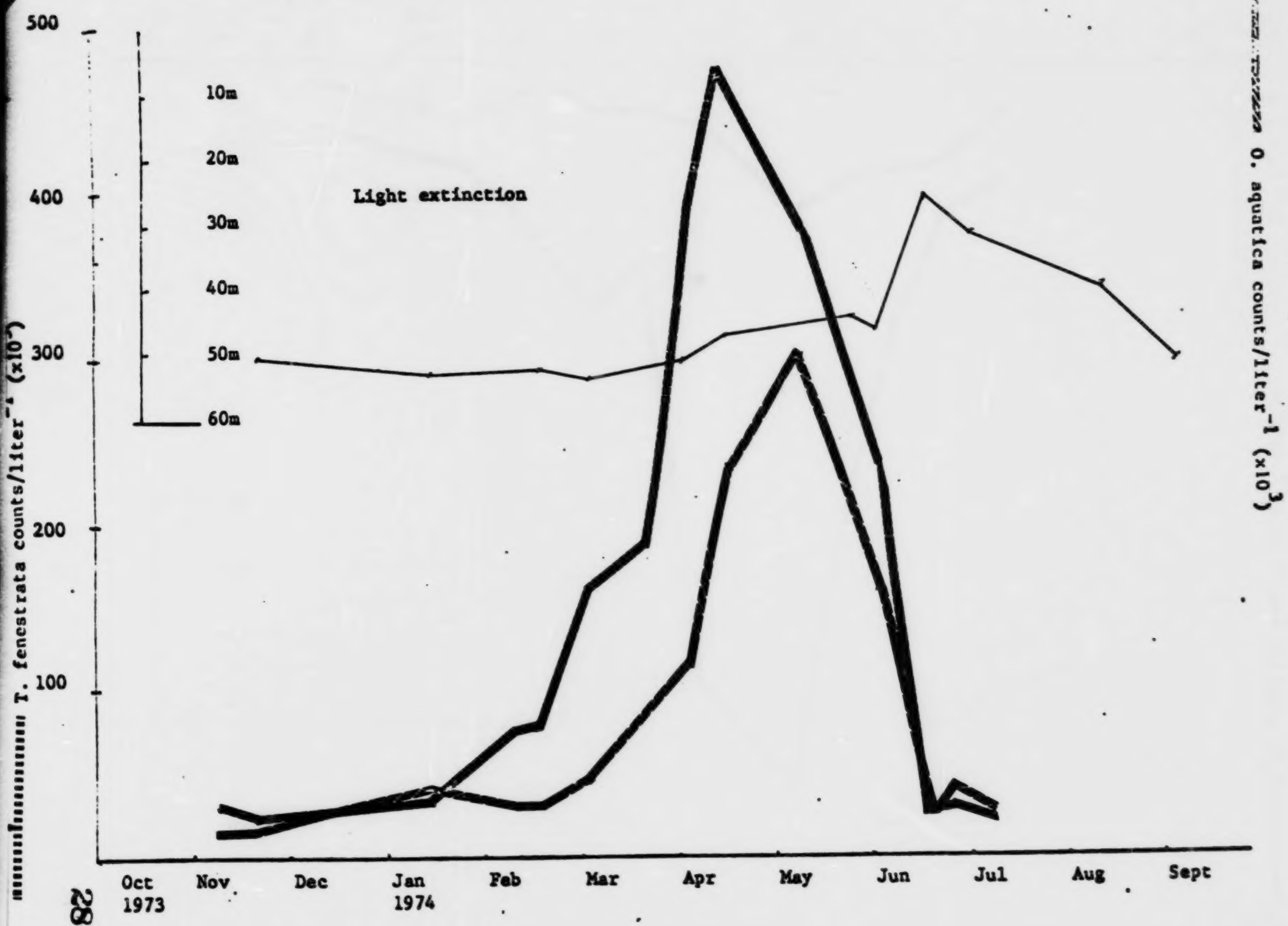
Tabellaria fenestrata (Lyngb.) Kütz var. *fenestrata*
Asterionella formosa Hess. var. *formosa*
Fragillaria crotonensis Kitton var. *crotonensis*
Oscillatoria aquatica Lyngb.
Melosira italica subsp. *subartica* Muller
Synedra spp.
Rhizosolenia eriensis H. L. Smith
Dinobryon sertularia Ehrenberg
Dinobryon bavaricum Imhoff

Net phytoplankton species composition was similar at bays and at open water stations. Spring peak counts for *T. fenestrata* were very similar except at the North End where April turbidity adversely affected production (Fig. 6-10). Seasonal dynamics of *O. aquatica* lagged just behind *T. fenestrata*, but intensity of the bloom varied. At North End and Skidoo Bay counts were low (Fig. 8 and 10); at Yellow Bay and the pelagic stations (Midlake, Yenne Pt, and Painted Rocks) maximum counts were about the same, ranging between

Light-*Tabellaria*-*Oscillatoria* dynamics in Yellow Bay. Fig. 6



Light-Tabellaria-Oscillatoria dynamics at Midlake. Fig. 7



Light-*Tabellaria*-*Oscilatoria* dynamics at Skidoo Bay. Fig. 8

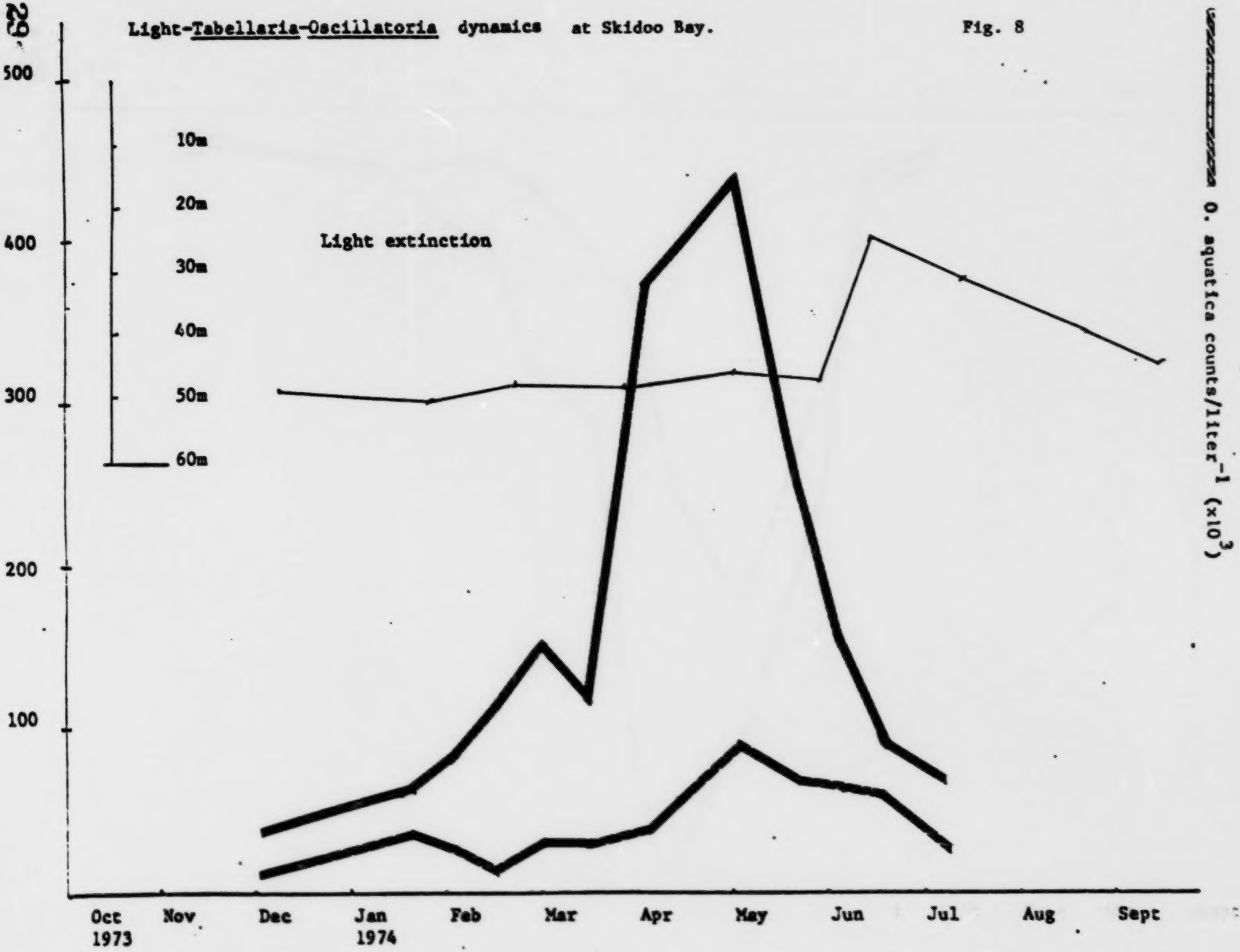
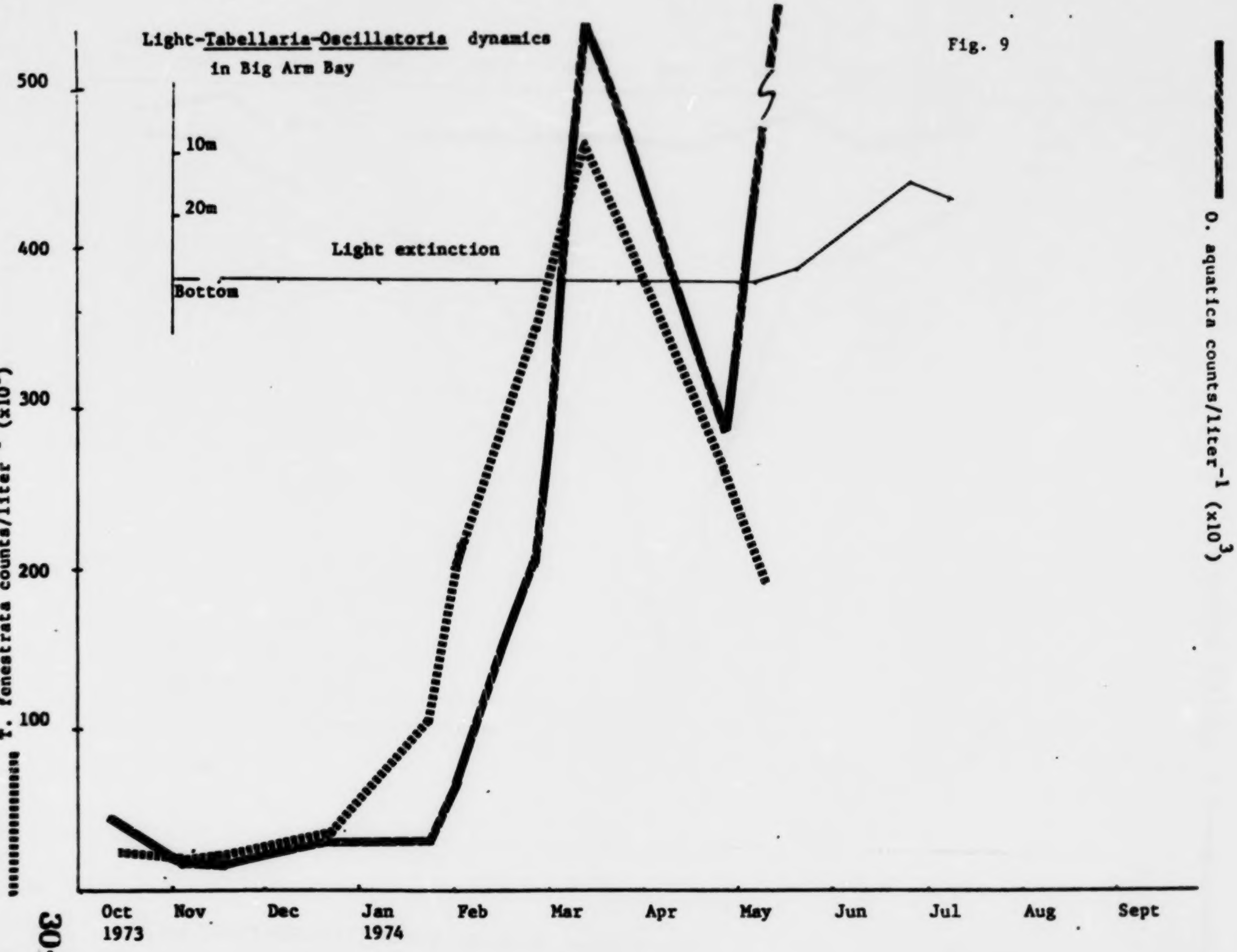
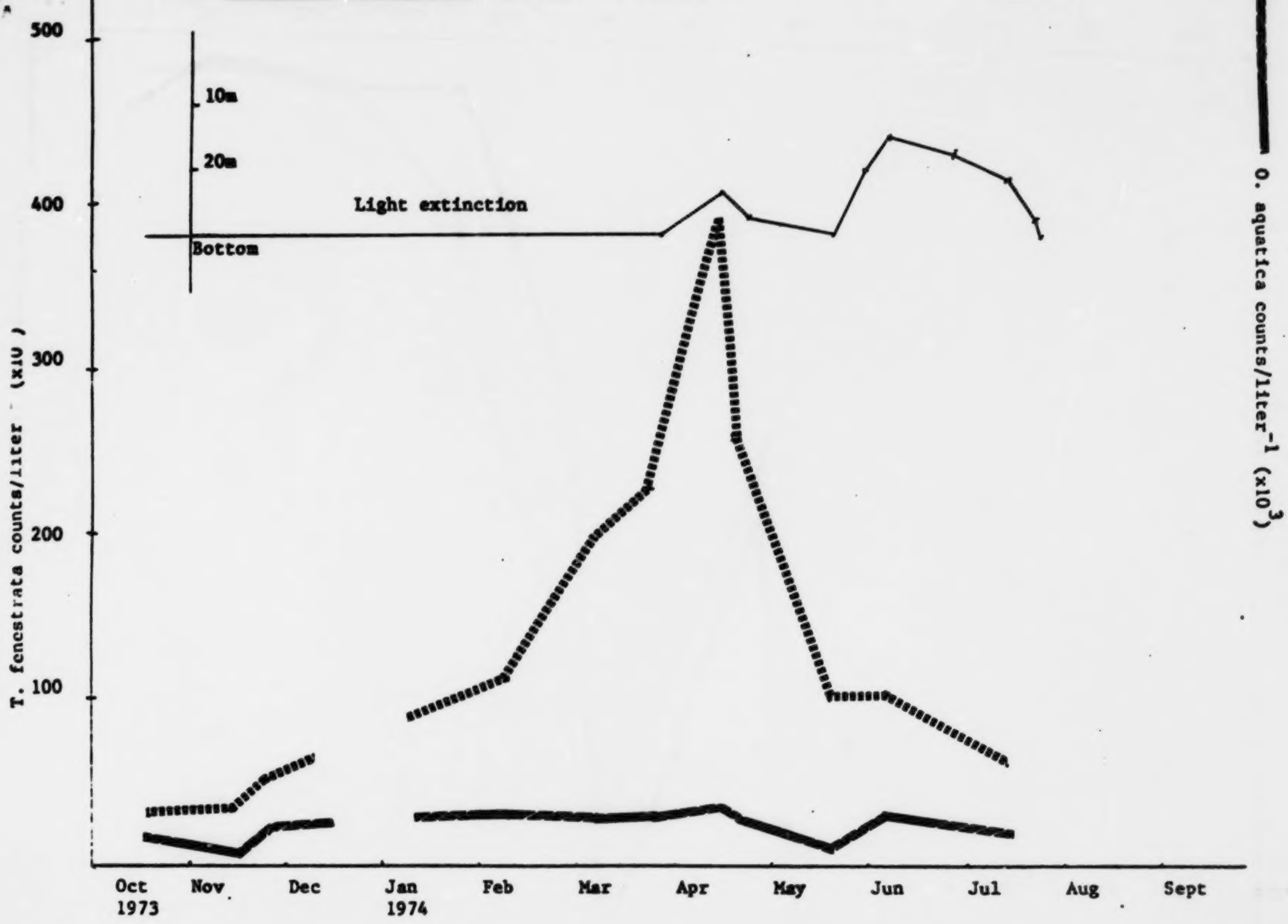


Fig. 9


Light-Tabellaria-Oscillatoria dynamics in Big Arm Bay

Light-*Tabellaria*-*Oscillatoria* dynamics at North End. Fig. 10



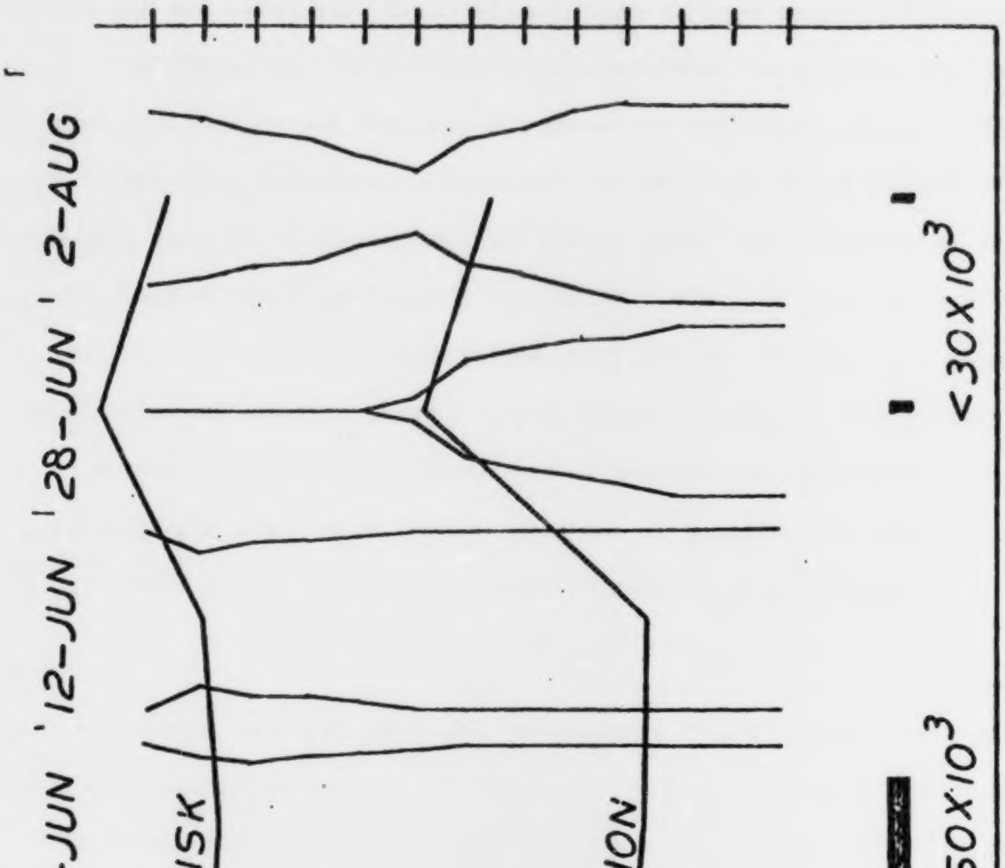
80×10^3 per liter and 120×10^3 per liter (Figs. 6 and 7); however, at Big Arm Bay counts reached more than 140×10^3 per liter and did not immediately decrease as June turbidity limited light availability (Fig. 9). Little variation in counts was observed due to sampling depth; net phytoplankton was about evenly distributed in the water column sampled at all stations. Mean values for the counts of the most abundant taxa are summarized for each station on all sampling dates in Appendix 1. Generally peak counts, for all phytoplankters enumerated, occurred in April also. The *Dinobryon* species were not present in counts until late spring and persisted through the turbid period. Fig. 11 illustrates depth profiles of turbidity in relation to available light and standing crop of *T. fenestrata* at Midlake station during early summer 1974.

Water Chemistry

In situ chemical-depth profiles to 100m with Hydrolab Surveyor 5 revealed that dissolved oxygen, conductivity, pH, and oxidation-reduction potential (ORP) remained quite constant lake-wide throughout the study. Dissolved oxygen was always present in concentrations near saturation regardless of depth, even during summer stratification. Per cent saturation values between 80 - 110 were regularly recorded. No more than 5 per cent variation within the water column was ever recorded at any station. Similarly, pH ranged from 7.8 - 8.1 and variations of not more than 0.5 pH units were recorded in any one depth profile. Conductivity was always 155-170 micromho per cm and no change was observed during the turbid period. ORP values varied from 3.7 - 5.7 millivolts. No seasonal dynamics could be documented for any of these parameters.

A listing of all laboratory chemical data is presented in Appendix 2. Annual ranges in data are given for each station in Table 5. Alkalinity,

Fig. 11


23-MAY
3-JUN
11-JUN
12-JUN
28-JUN
2-AUG
SECCHI DISK
LIGHT EXTINCTION
600X10^3
250X10^3
<30X10^3
1
10
20
30
40
50
60
DEPTH

33<

Table 5. Summary of Chemical Data, Sept. 1973 to Aug. 1974. mg 1-1

No.	Station Name	pH (in situ)	Total Hard	Total Alkal	Nitrate (as NO_3)	Phosphate (as PO_4)	Total Phos. (PO_4)	Silica (SiO_2)	Total Iron
1.	Yellow Bay	7.8-8.2	83-107	78-91	<.01-.30	<.03	<.03-.05	1.3-4.1	
2.	Midlake Deep	7.8-8.2	87-95	79-90	<.01-.40	<.03	<.03-.09	1.7-4.1	
3.	Yenne Point	7.8-8.2	85-99	79-87	<.01-.38	<.03	<.03-.05	1.6-3.9	
4.	Skidoo Bay	7.8-8.2	86-96	79-88	<.01-.41	<.03	<.03-.06	1.8-4.4	
5.	Polson Bay	7.8-8.2	81-97	79-88	<.01-.20	<.03	<.03-.06	1.9-5.5	
6.	Flt R. at Plsn	7.8-8.2	81-98	78-90	<.01-.67	<.03	<.03-.05	1.4-6.5	
7.	Big Arm Bay	7.8-8.2	86-96	78-87	<.01-.28	<.03	<.03	1.7-4.6	
8.	Flt. R. Mouth	7.7-8.4	86-101	71-90	<.01-.80	<.03	<.03-.25	2.3-5.4	
9.	Big Fork Bay	7.7-8.3	75-106	73-98	.01-.23	<.03	<.03-.21	2.1-6.7	
10.	Flt R. at Holt Bg.	7.2-8.4	83-97	81-97	.01-.91	<.03-.07	<.03-.54	2.0-6.5	
11.	Painted Rocks	7.8-8.3	84-93	77-88	.01-.34	<.03	<.03	1.8-4.1	
12.	Swan R. at Big Fk.	7.8-8.4	72-97	70-103	.01-.98	<.03	<.03-.36	2.6-7.0	
13.	North End	7.6-8.4	84-95	78-87	.02-.35	<.03	<.03-.07	1.7-4.1	

See Appendix 2

hardness, and CO_2 values indicate that Flathead Lake water is well buffered and moderately hard. Some discrepancies occurred between laboratory and in situ pH values indicating that shifts in the carbonate-bicarbonate system may have occurred during sample storage in laboratory refrigerators. However, these variations may have been entirely due to instrument error. Alkalinity and hardness data agree well with previous studies. No significant seasonal dynamics in alkalinity or hardness data were recognized.

Nitrogen and phosphorous data are most significant. Nitrate values ranged between 0.01 and 0.40 mg per liter at lake stations. Seasonal trends were similar at all lake stations with higher values being recorded generally during spring and fall circulation periods (Figs. 12 and 13). Nitrate values were much higher at the inflowing river stations. However, concentrations in samples from outflowing waters at Station 6 (Flathead River at Polson) were quite similar seasonally to those from lake stations. Phosphorous was rarely above minimum detectable concentrations at lake stations and Station 6. Unbound, inorganic PO_4 concentrations were never detectable. Total P was higher at inflowing river stations on occasion but the annual averages were near the detectable limits of 0.03 mg per liter.

Comparison of data from duplicate sets of samples from Stations 1, 2, and 3 (Yellow Bay, Midlake, and Yenne Point) which were analyzed at both the Institute of Water Research (Michigan State U.) and at the Helena Laboratory are given in Table 6. IWR utilized a more sensitive method of phosphorous detection (IWR, unpublished) and recorded very low concentrations. Nitrate values agreed fairly well. Total carbon was quite low as might be expected considering the low net phytoplankton counts obtained at the same time (Appendix 1).

Silica (SiO_2) concentrations were fairly low (1.3-2.5 m per liter) during winter and spring months. However, large amounts were apparently carried into Flathead Lake by heavy spring discharges as values reached 6.0-7.0 mg per liter during June and July. Seasonal dynamics of silica (SiO_2) at Yellow Bay and Midlake stations are illustrated in Figures 12 and 13. Other lake stations followed similar trends. The inflowing rivers and river mouth areas reached higher values during spring runoff.

Copper, cobalt, zinc, manganese and cadmium concentrations were always quite low, but detectable, at all stations at which samples were analyzed for these elements. Total iron, however, was always surprisingly high, with values ranging between 0-0.22 mg per liter (Table 5).

Algal Assay

Phosphorous concentrations greater than 0.003 mg/l added to filtered Flathead Lake water stimulated growth of *Selenastrum* in bioassay experiments. Nitrogen additions had no stimulatory effect. Nitrogen and phosphorous spikes added together stimulated growth irrespective of nitrogen concentration, but in direct proportion to phosphorus addition.

In situ phosphorous additions of 0.5 mg per liter also stimulated growth of indigenous algal flora (Table 7). No significant shifts in species composition were observed through the experimental period, however, *Tabellaria fenestrata* continued to dominate net phytoplankton, but total numbers were greater in response to phosphorous spikes.

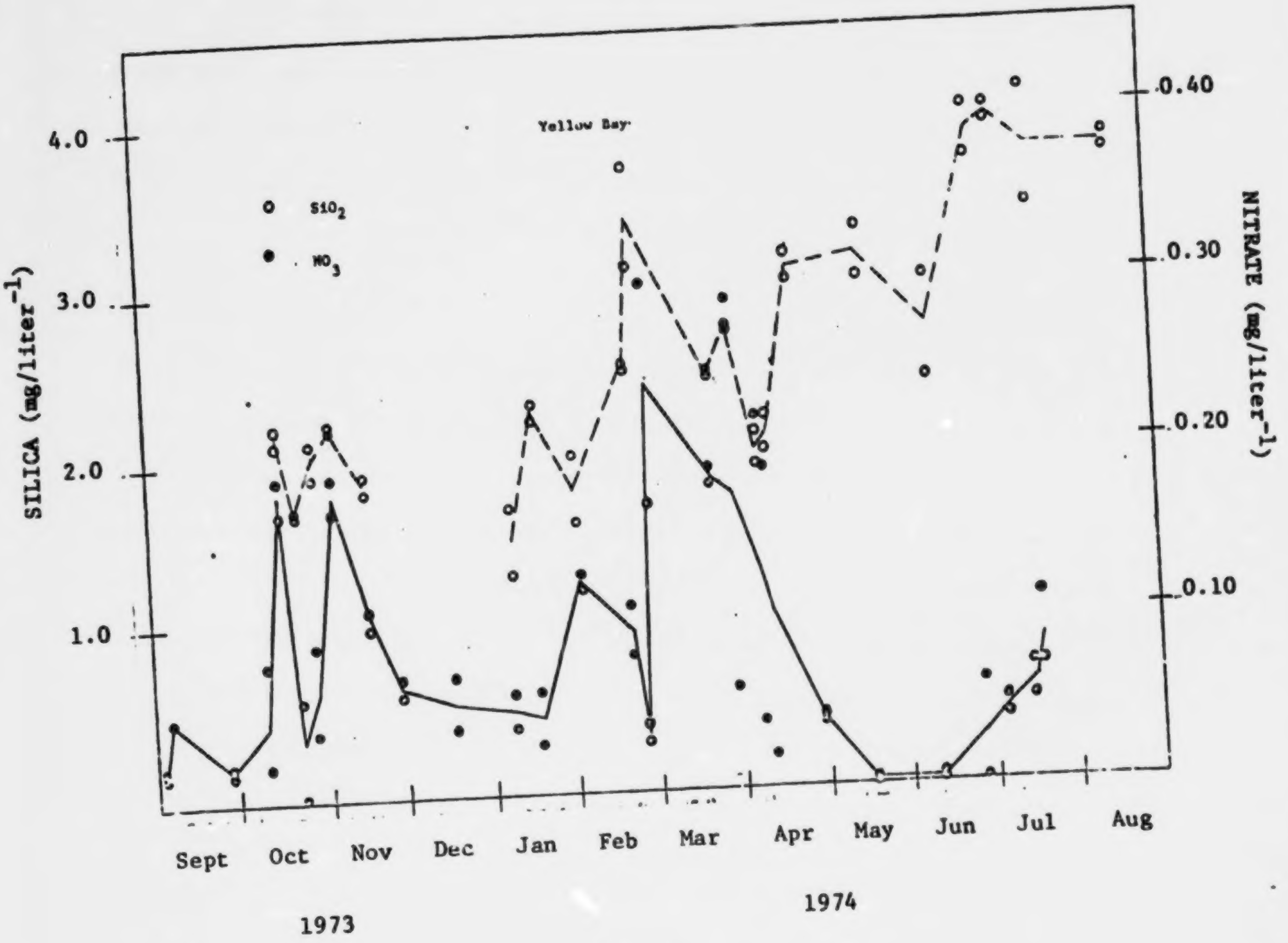

Yellow Bay
○ SiO_2
● NO_3
SILICA (mg/liter^{-1})
4.0
3.0
2.0
1.0
NITRATE (mg/liter^{-1})
0.40
0.30
0.20
0.10
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
1973
1974

Fig. 12

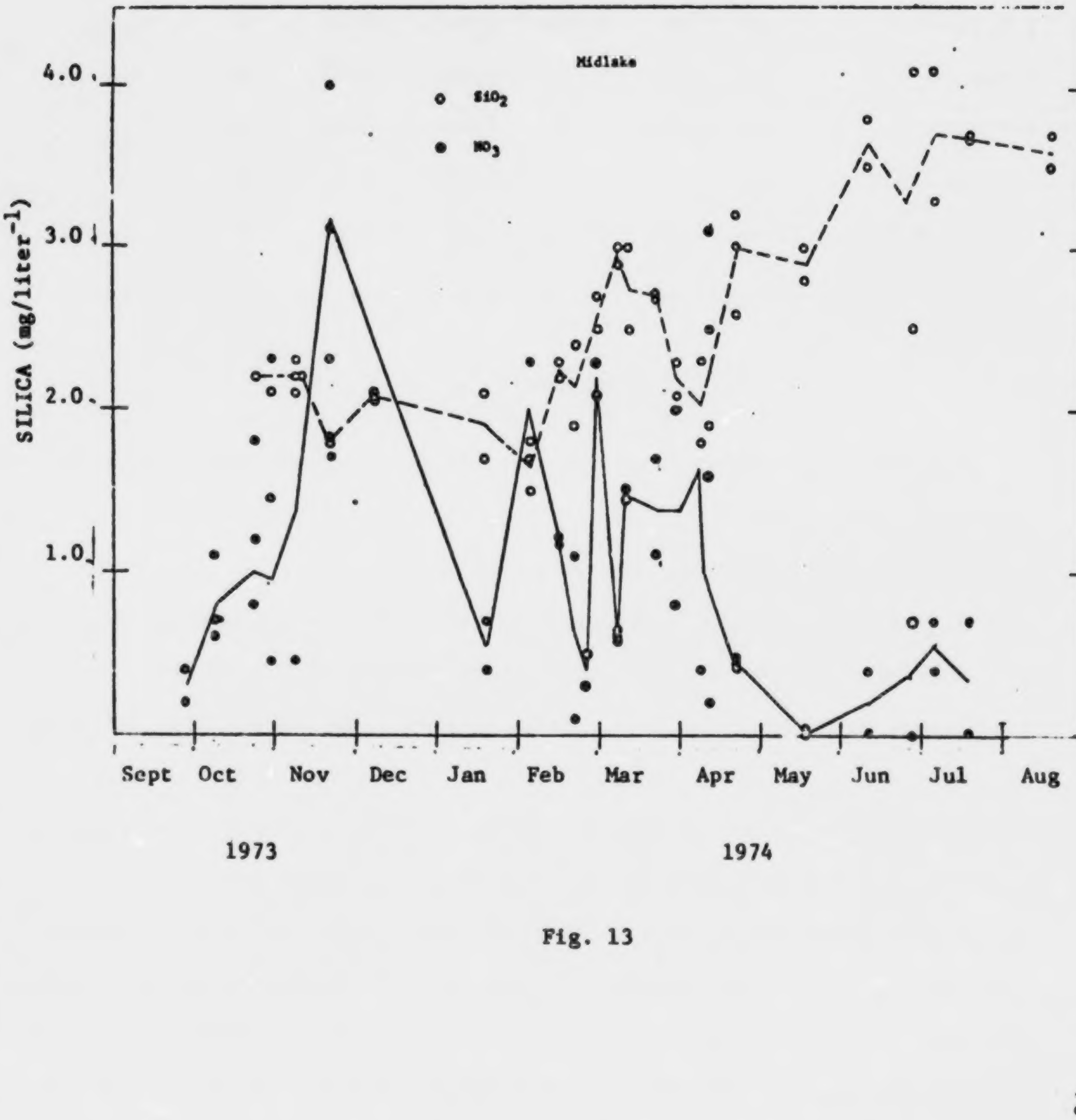

Midlake
○ SiO_2
● NO_3
SILICA (mg/liter^{-1})
NITRATE (mg/liter^{-1})
4.0
3.0
2.0
1.0
0.40
0.30
0.20
0.10
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
1973
1974

Fig. 13

Table 6. Comparison of data from midlake samples collected 25/II/74 and analyzed by IWR and Montana State personnel.

Station	Depth	Nitrate Nitrogen mg/l-N		Total Phosphorus mg/l-P		Total Carbon mg/l-C
		IWR	State	IWR	State	IWR
1-Yellow Bay	1m	0.01	0.01	0.004	0.01	21
1-Yellow Bay	25m	0.01	0.01	0.007	0.01	21
2-Midlake	1m	0.01	0.03	0.004	0.01	20
2-Midlake	40m	0.01	0.05	0.03	0.01	20
3-Yenne Point	1m	0.01	0.01	0.005	0.01	20
3-Yenne Point	40m	0.01	0.01	0.004	0.01	20

DISCUSSION

Previous reports of species compositions of dominant Flathead Lake net phytoplankton are different from that reported here in two respects. Tabellaria quadrisepta Kunds. was listed by Morgan (1968, 1971) and Ivory (1973) as the most abundant phytoplankter rather than T. fenestrata. Apparently Morgan incorrectly identified the diatom. We did observe T. quadrisepta on occasion and this species appears on Gaufin's (1974) indigenous species list; it was never abundant, however, during our study. We were, however, quite surprised to find the unreported blue green alga, Oscillatoria aquatica in such high numbers at all lake stations. Other bluegreen populations have been observed in Flathead Lake but only in rather stagnant, isolated shoreline areas probably in response to localized nutrients seepage from septic tanks (U. Mont. Biol. Stat., unpubl. data). No evidence of limnetic bluegreen blooms have been reported previously. O. aquatica occurs as small, inconspicuous filaments, but we had no difficulty making counts. It seems unlikely that this plankter could have been overlooked in previous studies if it were present in similar densities. Morgan (1968, 1971) and Ivory (1973), however, concentrated plankton by centrifuging 500 ml samples through a Forrest plankton centrifuge. This method breaks up algal colonies and destroys many of the more delicate cells (Gaufin, unpubl. data). It is possible that the rather fragile strands of _O. aquatica_ could have been broken by centrifugation and not recognized by Morgan nor by Ivory. Moghadam (1969) studied primarily diatom taxonomy and her acid-boiled, hyrax-mounted preparations of diatom frustules prevented examination of other algae. Young (1935) would have reported _O. aquatica_ if it had occurred. It is unclear whether this plankter is a new arrival in Flathead Lake, whether its earlier smaller populations have now become appreciable, or whether it has merely been overlooked by previous investigators. Perhaps it is only abundant in certain years, responding to some uncommon combination of environmental stimuli. The abundance of _O. aquatica_ during 1973-1974 clearly establishes the alga as an important phytoplankter in the Lake and further investigation of its ecology is warranted.

Peak standing crops of net phytoplankton were higher in the present study than reported by Morgan (1971). This may not be due to increased productivity since 1969. Rather it may be that Morgan's centrifugation process may have biased counts by destroying diatom colonies and possibly even substantial numbers of cells. Furthermore, Morgan's small sample size (500 ml) may not have adequately sampled the sparcely distributed plankton populations. Our counts were derived from sedimentation of 3 liter samples. No damage and little or no loss of cells was encountered; our counts were quite reproducible.

Net phytoplankton species composition and population dynamics in addition to low limnetic phosphorus concentrations reported here characterize Flathead Lake as oliogotrophic according to Vollenweider's (1970) classification scheme. The limnology of the bays corresponded well with that of the open water areas indicating that the Lake functions as a unit. However, areas around the mouth of the Flathead River were more dramatically influenced by river discharges. Spring nutrient circulation, warming temperatures, and increasing photoperiod stimulated net phytoplankton bloom in the bays and pelagic areas alike with slightly higher intensity in Big Arm Bay. Notably, phytoplankton density was similar throughout the 40 m photic zone. Turbidity severely reduced net phytoplankton production in early summer. An apparent lack of nutrient additions during high spring discharges was strongly indicated by the failure of net phytoplankton to re-establish populations in late summer and fall after the water column began to clear. Chemical analysis also showed that there were no additions of nutrients except for silica which was always present in fairly high concentrations. The lack of increase in conductivity was especially indicative of the inert nature of the materials causing the turbidity. Notice, however, that at all stations except Big Arm Bay, standing crops were rapidly decreasing in May before the onset of severe clay turbidity, indicating that a nutrient limitation had already occurred. Unfortunately chemical data did not reveal a significant corresponding nutrient dynamic in detectable concentrations.

Concentrations of phosphorus in Flathead Lake observed in the present study were dramatically lower than previously reported. It is surprising that validity of previous data has not been seriously questioned since the phosphorous concentrations in Flathead Lake reported by Potter and Baker (1961), Morgan (1968, 1971) and even USGS (1970) data upon which Seastead and Tibbs (1973) based their loading predictions compare nicely with values given for grossly enriched Lake Washington (Edmonson, 1969) and western basin of Lake Erie (Cole, 1973). Out nitrate nitrogen data, however, were quite similar to previous values.

Based on 40 year average flow data in the Swan and Flathead Rivers at Flathead Lake (USGS, 1972) and chemical data gathered during the study we calculated the approximate nitrate nitrogen and total phosphorus input into the Lake during the period August 1973 to August 1974 (Table 8). If we may assume this nutrient input and metabolism of nutrients within the Lake has been fairly constant over the last 2.37 years (ie. corresponding to mean water retention time), it is apparent that about two thirds of the NO_3-N that entered the lake via the rivers was not discharged. Phosphorous loading data were based on maximum possible concentrations; on most occasions total phosphorus was found to be less that the minimum detectable concentrations, but loading calculations were made giving less than detectable concentrations a value of 0.03 mg per liter even though they were probably much lower. As with nitrate nitrogen, about two thirds of the total phosphorus entering the Lake was not discharged. Note, however, that virtually all of the phosphorus was organically bound; very little free PO_4

Table 8. Nitrate and phosphorus loading in Swan River and Flathead River above and below Flathead Lake, 1973-4. Figures are in metric tons expressed as N and P.

	Nitrate	Phosphorus
Swan R.	168	18
Flathead R. at Holt Bridge	789	232
Total Input	957	251
Flathead R. at Polson	352	180
Loss within Flathead Lake	605	71

was detected in river discharges and no phosphorus left the Lake in that form (Appendix 2), at least in our detectable range. Probably all phorphorus leaving the lake was organically bound in living phytoplankton biomass discharged downstream. Unfortunately, we were unable to obtain organic nitrogen data. USGS (1970) data indicated that two thirds of nitrogen in Flathead River lake discharges during 1969-70 was organically bound. The figures in Table 8 do not include recrutiment of nitrate-nitrogen or phosphorus from other potential sources such as lake surface precipitation, shoreline septic tank seepage and shoreline agricultural runoff.

Nitrate nitrogen concentrations increased during fall and spring circulation periods at lake stations; this suggested nitrate release from sediments or recirculation of sedimented nitrogen as nitrate from profundal areas of the Lake. No seasonal dynamics in phosphorus could be demonstrated at lake stations. Seasonal dynamics must have occurred, however, corresponding to net phytoplankton blooms. Phosphorus dynamics were likely in the range of <.001-009 mg per liter as indicated by the total phosphorus values obtained in samples analyzed by Institute of Water Research. Pechlaner (1970) reported spring diatom bloom in Lake Erhen (Sweden) followed phosphate phosphorus concentrations of not more than 0.010 mg per liter. Planktonic diatoms such as those abundant species in Flathead Lake are known to maintain bloom populations on very low concentrations of phosphorus and Asterionella formosa has been shown to take up inorganic phosphorus in concentrations of as little as 0.0001 mg per liter (Mackereth, 1953). Silica and trace metals appeared to be present in sufficient amounts not to be limiting to phytoplankton production at any time in Flathead Lake. Inorganic phosphorus was always near minimum detectable concentration, even in river discharge into Flathead Lake during spring runoff; the upper Flathead River drainage apparently does not release much soluble inorganic phosphorus. Cultural additions of phosphorus are increasing (Seastead and Tibbs, 1973), but it appears that all inorganic phosphorus is organically bound before it reached the Lake. Phosphorus cycles rapidly in lakes and there is some evidence that phytoplankton can utilize complex organic phosphorus metabolites directly without conversion to free phosphate (Lean, 1974). Rapid cycling of very low phosphorus concentrations must occur in the photic zone of Flathead Lake, especially during the spring when the greatest net phytoplankton production occurred.

Sediments from cores taken in Flathead Lake were analyzed for total phosphorus. The Montana State Department of Fish and Game kindly assisted us with the coring operation. Samples from the surface of the cores as well as from various depths in the cores were analyzed to provide information on the possible present and past accumulations of phosphates in these sediments. Only one of the twenty samples revealed more than a trace of phosphorus. We conclude that phosphorus which may be released from Lake sediments would provide only insignificant amounts of that nutrient in the water.

Our phosphorus and nitrogen data indicate Seastead and Tibbs (1973) may have greatly overestimated loading of these nutrients in Flathead River discharges. Our calculations only approximate nutrient budgets for Flathead Lake. Seasonal organic nitrogen data are needed along with knowledge of phosphorus and nitrogen released from sediments, precipitation nutrient additions at Lake surface, and phytoplankton nutrient assimilation rates. However, our loading estimates strongly suggest that nitrogen is present in sufficient concentrations to support additional phytoplankton biomass. Lack of available phosphorus is apparently a large factor in suppressing phytoplankton production. These conclusions were supported by algal assay experiments.

During the 1973-4 study period, roughly 70 metric tons of phosphorus and 605 metric tons of nitrate nitrogen were either permanently tied up in biomass and/or lost to Lake sediments. Again, this is based on the assumption that the ratio of nitrate-nitrogen and total phosphorus received to that discharged was constant and directly related to annual dynamics of the same nutrients within the Lake during the time for which the calculations were made. Presumably, most of this phosphorus was bound in bottom sediments in such form that resuspension was severely limited, because total phosphorus values were always very low or undetectable in the water column. Much less may be said about nitrogen, due to lack of organic nitrogen data. It is clear, however, that substantial amounts of nitrogen were also tied up by lake processes.

Chemical and physical hydrodynamics provide plausible explanations for nitrogen and especially phosphorus losses. In the presence of dissolved iron, phosphorus will precipitate as iron phosphate, as long as oxidizing (aerobic) conditions exist (Sridharan and Lee, 1974). Our dissolved iron and oxygen data indicate similar conditions existed in Flathead Lake. Inorganic phosphorus complexed as iron phosphate in bottom sediments could not be re-suspended unless an anaerobic (reductive) mud-water interface developed. Furthermore, reducing conditions or a paucity of dissolved iron would have to exist between the sediments and the photic zone before any released phosphate could be utilized by phytoplankton. Dissolved total iron was always fairly high during the study and there was no evidence that surface sediments or any part of the water column were ever in a reducing (anaerobic) condition anywhere in the pelagic area of Flathead Lake. It appears, then, that as long as iron is available, phosphate could be precipitated and lost from the functioning Lake ecosystem.

The annual clay turbidity observed in Flathead Lake may also be playing a major role in phosphorus cycling. Lee (1970) and Wildung and Schmidt (1973) have shown that phosphorus may be adsorbed to the surface of fine clay particles. In fact, Golterman (1974, personal communication) has shown that phosphorus concentrations may be reduced to levels severely limiting primary production by phosphorus sorption of montmorillonite and kaolinite clay turbidity. Considering the similar clay turbidity and the manner in which we have described the plume to spread over the lake surface and then sink, clay sorption and permanent sedimentation of phosphorus may well account for some phosphorus losses. The very low standing crops of net phytoplankton observed after the photic zone cleared of turbidity suggests primary production was nitrient limited. Nitrate as well as phosphorus concentration was quite low at that time. Lee (1970) points out, however, that nitrogen has less afinity for clay sorption than does phosphorus. During the turbid period we observed seston in clumps composed of organic detritus and phytoplankton adhering to an inorganic (presumably clay) substrate. Therefore, the clay turbidity may also function as a floculation agent, clearing the water column of seston. Large amounts of organic nitrogen and phosphorus could be lost to the lake sediments in this manner. By means of such "stripping" phenomena the turbidity is very likely the most important hydrodynamic feature of the Lake in terms of maintaining very high transparency of water during late summer, fall and winter.

In order for the spring growth of net phytoplankton to begin, regeneration of available phosphorus and nitrogen in photic zone had to occur. Recirculation of Nitrate released in profundal areas of the lake is a possibility, but most of the nutrient probably was derived from tributary rivers during fall and winter. Regardless of source, nitrate regeneration in photic zone is documented here. Unfortunately we did not have analytical capability to monitor spring phosphorus dynamics which must have been in range of 0.0001 to 0.009 mg per liter.

The occurance of the blue green alga, *Oscillatoria aquatica* is very significant in regard to nutrient availability. Certain species of *Oscilatoria* are known to be capable of nitrogen fixation and often sustain high population densities in presence of very low nitrogen and phosphorus concentrations (Hutchinson, 1974). Nuisance bluegreen blooms often follow spring blooms of diatoms which have reduced nitrogen and phosphorus to low concentrations (Hutchinson, 1957). Bluegreens, such as *Oscilatoria* and *Anabaena* are better competitors for very low phosphorus and can fix their own nitrogen (Shapiro, 1973). Pechlaner (1970) has documented a spring diatom outburst in Lake Erhen (Sweden). The bloom was stimulated by increasing photoperiod, 0.02 mg per liter PO_4-P, and 0.15 mg per liter NO_3-N. Bluegreen algae (*Anabaena flos-aquae* and *Aphanizomenon flos-aquae*) began to diminate when nutrients were reduced to 0.003 mg/l PO_4-P and 0.015 mg/l NO_3-N. This pattern closely resembles that observed in Flathead Lake; except that in the latter case bluegreen algae (*Oscillatoria aquatica*) production decreased as turbidity ensued, apparently limited by low light and nutrients. Should turbid conditions not have occurred, intense primary production may have continued into summer months with bluegreens dominating the plankton community.

The present study has documented spring turbidity movement and consequences, demonstrated phosphorus limitation, and documented diatom-*Oscillatoria* standing crop dynamics in relation to light and water chemistry. However our efforts toward defining nutrient (P and N) budgets for the lake were only moderately successful. Further study of assimilation rates, sediment release and sorption and phosphorus dynamics are badly needed. We failed to consider nannoplankton organisms which Kalff (1977) has shown often are major primary producers in oligotrophic lakes. We have no estimate for the amounts of phosphorus the Lake might assimilate on an annual basis before changes in algal species composition and production occur. Documentation of the true phosphorus dynamics requires analytical capability in .1 - 10 ug/liter range. It is clear, however, that discharges from Flathead River do contain phosphorus concentrations well within range necessary for nuisance pelagic blooms of bluegreens to develop should the physical mechanisms of phosphorus loss be overcome.

Edmondson (1972), Shindler (1974) and Shindler et al. (1972) have convincingly shown that the eutrophication process is most dependent on phosphorus because nitrogen is usually present in sufficient concentrations or, if not, bluegreen algae can fix their own. Also, they have proven that total primary production in phosphorus sensitive lakes is related to the ratio of phosphorus added to phosphorus lost by natural processes. Therefore, in such lakes, especially those which are deep enough to stratify, primary production will become phosphorus limited when phosphorus input is eliminated. Management of primary production in Flathead Lake hinges on further understanding of actual phosphorus dynamics in the Lake as well as its tributaries and a quantitiative knowledge of the Lake's ability to maintain a phosphorus deficit. G. W. Prescott (personal communication) was certainly correct in observing earlier that phosphorus is probably the mainspring of primary production in Flathead Lake. Critical values, however, are an order of magnitude lower than he supposed.

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APPENDIX 1:

Average net phytoplankton count

at each station on each sampling date

Mean Raw Counts per liter - Yellow Bay D=25m

PHYTOPLANKTER

Date	T.fenestrata	A.formosa	F.crotonsis	Melosiria spp.	Synedra spp	Dynobryon spp	O.aquatica	R.eriensis
8/x/73	16,379	<1,000	<1,000	<1,000	<500	-	<1,000	
17/x/73	16,440	4,008	1,115	3,488	652	-	1,210	
29/xi/73	5,630	4,423	3,204	3,832	851	-	2,041	
18/I/74	43,584	12,877	8,150	6,744	2,273	<500	7,366	
21/II/74	82,362	20,257	11,887	8,137	2,816	581	7,219	
29/III/74	312,351	57,572	12,868	10,377	5,548	961	10,193	
11/IV/74	421,034	110,727	16,777	13,590	2,961	3,761	32,157	
17/IV/74	487,905	85,590	24,605	4,491	2,625	<500	69,797	
22/IV/74	489,840	129,554	14,584	7,729	3,843	<500	65,365	
17/V/74	469,359	53,210	18,621	7,926	6,073	<500	120,993	
6/VI/74	192,712	8,896	6,008	5,551	1,696	-	43,409	
27/VI/74	34,063	1,807	3,060	1,388	523	-	3,844	
5/VII/74	28,443	5,814	3,864	2,373	1,174	-	7,651	
18/VII/74	15,759	4,695	2,730	<1,000	<500	-		

Raw Counts - Averaged Yellow Bay D=25m

MEAN RAW COUNTS PER LITER - Deep Water - D=110m

PHYTOPLANKTER

Date	T.fenestrata	A.formosa	F.crotensis	Melosira sp	Synedra spp	O.aquatica	D.bavaricum
1/xi/73	21,282	4,311	3,346	2,064	1,121	1,352	<1,000
1/xi/73	12,167	5,199	1,661	2,128	3,181	<1000	<1,000
8/I/74	24,498	15,756	3,797	7,446	3,927	7,3111	<1,000
5/II/74	72,788	20,078	3,113	8,791	1,540	4,716	<1,000
21/II/74	75,303	20,447	4,173	13,808	1,685	5,090	<1,000
/III/74	160,639	37,995	14,091	16,925	4,399	9789	<1,000
29/III/74	193,361	54,045	10,798	12,018	1,350		<1,000
11/IV/74	406,729	116,158	16,673	22,429	8,654	21,549	<1,000
22/IV/74	489,128	108,268	16,725	11,755	6,144	60,630	4,251
17/V/74	389,492	63,238	12,205	5,893	1,871	77,699	5,680
11/VI/74	238,922	7,697	17,071	1,000	1,793	40,473	74,807
27/VI/74	25,099	2,136	3,909	4,610	1,000	4,343	24,896
5/VII/74		17,236	2,542	4,645	1,016	8,300	10,561
18/VII/74	11,793	7,282	3,350	-	<1,000	<1000	961

MEAN RAW COUNTS PER LITER - Skidoo Bay - D=60m

PHYTOPLANKTER

Date	T.fenestrata	A.formosa	F.crotonensis	Melosira	Syndedra spp	Dynobryon	R.erensis	O.aquatica
4/XII/73	30,039	7,095	5,687	6,006	536			<1000
24/I/74	58,505	22,135	6,794	13,188	734			6850
8/II/74	80,076	19,450	7,044	12,021	960			3220
21/II/74	110,931	18,855	6,321	12,321	1,829			
7/III/74	152,917	32,819	9,685	17,737	1,101			5650
22/III/74	133,154	4,532	3,685	7,850	508			5339
11/IV/74	386,500	62,473	17,106	16,115	2,599			7046
11/V/74	450,308	33,595	15,826	9,528	1,864			21,987
29/V/74	251,698	11,874	11,784	5,035	1,565			15,431
13/VI/74	153,978	5,480	8,644	14,077	859			14,362
27/VI/74	85,945	8,023	4,880	4,308	1,572			13,263
11/VII/74	60,075	15,008	7,175	4,152	621			4,816

MEAN RAW COUNTS - POLSON BAY - D=6m

PHYTOPLANKTER

Date	T.fenestrata	A.formosa	F.crotensis	Melosira spp	Syndedra spp	Dynobryon	R.erensis	O.aquatica
11/X/73	34,888	6,441	11,017		536			<1000
4/XII/73	25,848	22,882		4,661	1,271			4,231
24/I/74	73,661	31,470		13,362	918			<1000
8/II/74	52,813	6,554		9,986	367			<1000
21/II/74	176,732	34,719	7,119	8,898	508			2,542
7/III/74	150,798	50,906	16,378	15,848	480			<1000
22/III/74	88,816			3,220	1,130			
11/IV/74	278,163	83,238	23,758	7,613	586			16,115
11/V/74	453,412	43,787	24,012	7,768	2,825			
29/V/74	136,207		5,254	4,209	480			
13/VI/74	133,679	9,266	2,825	6,073				
27/VI/74	51,655	5,122	5,028					
18/VII/74	66,105		4,407		734			

MEAN RAW COUNTS PER LITER - YENNE POINT D=80m

PHYTOPLANKTER

Date	T.fenestrata	A.formosa	F.crotensis	Melosira	Syndedra spp	Dynobryon	R.erensis	O.aquatica
9/XI/73	38,069	9,336	2,683	3,041	847			4,972
15/XI/73	31,866	5,799	2,909	5,558	960			4,294
30/I/74	51,455	8,117	3,390	10,946	437			8701
11/II/74	66,952	15,286	2,712	8,478	433			1807
9/III/74	160,975	28,691	7,881	11,285	508			847
26/III/74	185,200	45,215	12,976	9,153	1,041			
17/IV/74	435,633	48,808	16,146	10,735	3,239			17,902
23/IV/74	553,218	49,359	14,047	11,098	1,995			13,200
22/V/74	215,020	8,832	5,292	4,901	1,200			10,283
11/VI/74	164,333	8,531	9,451	4,990	1,017			8,152
17/VII/74	56,942	17,430	4,350	1,751	904			7,208

MEAN RAW COUNTS PER LITER - BIG ARM BAY D=40m

PHYTOPLANKTER

Date	T.fenestrata	A.formosa	F.crotensis	Melosira spp	Syndedra spp	Dynobryon	R.erensis	O.aquatica
9/XI/73	15,675	8,787	2,043	2,741	1,094			8,382
4/XII/73	10,237	4,191	2,088	3,839	3,587			2,990
13/XII/73	16,595	26,725	2,655	4,919	6,942			4,799
24/I/74	31,778	19,826	4,421	8,739	4,542			6,935
15/II/74	107,835	44,096	9,382	26,572	2,512			6,107
7/III/74	203,835	82,370	20,201	14,097	3,457			15,914
29/III/74	355,430	84,780	16,906	8,783	4,675			51,048
15/IV/74	467,829	121,655	15,793	9,488	6,122			137,819
29/V/74	258,877	8,413	16,447	5,162	<1,000			72,555
13/VI/74	193,471	4,786	19,176	110,070	4,244			198,584

MEAN RAW COUNTS PER LITER - NORTH END D=30m

PHYTOPLANKTER

Date	T.fenestrata	A.formosa	F.crotensis	Melosira spp	Syndedra spp	Dynobryon	R.erensis	O.aquatica
18/X/73	26,131	11,695	3,691	2,429	423			3,107
15/XI/73	31,753	15,099	2,542	4,197	3,540			4,237
26/XI/73	46,523	12,990	2,674	6,421	5,214			<1,000
11/II/74	109,359	15,012	5,415	11,445	4,939			6,017
9/III/74	198,363	41,588	12,467	9,741	1,288			5,508
26/III/74	239,414	64,341	12,494	9,605	2,198			6,189
17/IV/74	395,675	67,754	14,588	11,985	2,010			7,542
23/IV/74	259,891	21,768	7,919	6,751	3,550			6,642
22/V/174	98,128	1,000	4,783	2,034				
10/VI/74	103,467	6,059	4,675	4,548	955			6,723
17/VII/74	61,237	10,254	7,119	3,408	725			3,757

APPENDIX 2:

Tabulation of all Chemical Data.

(1) Yellow Bay

ATE	pH	Si	T Hard.	Ca	Mg	Alk	Co_2	No_3	T Phos/O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
2-VIII 73								.01	.04/.01		21.8						S
								.01	.03/.01		16.5						D
10-VIII 73								.01	.04/.01		21.5						S
								103	.07/.04		19.0						D
22-VIII 73								.02	.02/.01		20.0						S
								.03	.03/.02		15.0						D
29-VIII 73								.02			20.5						S
								.02			---						D
3-IX 73								.02			17.5						S
								.02			17.5						D
4-IX 73								.05			8.0						27
21-X 73								.02			18.0						1
8-X 73								.04			12.5						1
								.08			13.0						10
								.02			7.5						27

(1) Yellow Bay II

two

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
17-X-73		2.1	8.6			91	3	.17	0		12.5						1
		2.2	87			89	5	.19	0		9.0						26
23-X-73	8.0	1.7	92			86	3	0	<.01		-						1
	7.7	1.7	88			86.7	4.8	.06	<.01		-						27
30-X-73	8.1	1.9	86			87	3.0	.04	<.01		9.0						1
	8.1	2.1	86			86.5	3.0	.09	.10/.01		9.0						10
6-XI-73	7.3	2.2	90.4			86.2	4.5	.19	.10/<.01		6.0						1
	7.6	2.2	95.8			86.4	4.5	.17	.04/<.01		5.0						30
19-XI-73	7.4	1.8	85.0	62.0	23.0	85.7	2.9	.10	.07/<.01		6.0						1
	7.5	1.9	85.8	62.0	23.8	86.0	3.2	.11	<.01		6.0						25
30-XI-73	7.4	1.8	88.2	61.9	26.3	85.8	3.2	.06	<.01		5.5	.05	<.01	<.01			1
	7.48	1.9	87.0	62.5	24.5	84.5	2.7	.07	<.01		5.5	.06	<.01	<.01			25
17-XII-73								.04	.01/<.01		5.2	.01	<.01	<.01			1
								.07	.02/		5.1	0	.01	<.01			25
9-1-74	8.3	1.3	89.8	63.0	23.8	85.5	3.3	.04	.01/<.01		1.0	.06	<.01	<.01			1

f

(1) Yellow Bay

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	$\frac{\text{T Phos}}{\text{O Phos}}$	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
5-VII 74	8.0	-	84.5	66.5	18.0	80.8	3.5				-	0	<.01	.03	0	<.01/ <.001	1
	8.1	-	90.0	69.5	20.5	84.5	3.5				-	0	<.01	.02	0	"	25
15-VII 74												.01	.04	<.01	0	"	25
												0	<.01	.02	0	"	1
18-VII 74	8.1	-	86.5	60.5	26.0	80.5	3.5				-	0	"	.01	0	"	1
	7.85	-	91.5	64.0	27.5	84.0	4.0				-	0	<.01	.01	0	"	25

one

ATE	pH	Si	T Hard	Ca	Mg	(2) Midlake Deep			T Phos								
						Alk	Co_2	No_3	O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
-VIII 73								.01	.02/.02		21.0						S
								.03	.04/.01		10.0						D
2-VIII 73								.03	.04/.01		70.5						S
								.01	.02/.02		18.5						D
9-VIII 73								.03			18.0						S
								.04			18.0						D
3-IX 73								.06			17.0						S
7-IX 73								.02			15.5						1
								.04			6.5						40
8-X- 73								.06			13.5						1
								.07			13.0						10
								.11			6.0						40
3-X- 73	7.6	2.2	88			87	4.2	.08	<.01		-						1
	7.5	1.8	88			87	4.5	.12	<.01		-						40
1-X-	8.1	2.1	87.4			87	2.9	.04	<.01		10.0						1

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DATE	pH	Si	T Hard	Ca	Mg	(1) Alk	Yellow Bay CO_2	NO_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
9-I-74	8.3	1.7	90.0	63.6	23.6	86.5	3.8	.06	<.01		4.0	.06	<.01	<.01			25
18-I-74	8.25	2.2	88.9	62.4	26.5	85.5	3.5	.03	.02/		3.0	.06	<.01	.01			1
	8.25	2.3	88.0	63.8	24.2	85.2	3.3	.06	.01/<.01		3.0	.01	<.01	-			25
4-II-74	8.3	1.6	88.5	65.5	23.0	86.5	4.0	.13	<.01/		2.5	0	<.01	.01			1
	8.15	2.0	91.0	63.0	28.0	85.8	4.0	.1.2	<.01/		2.5	.30	<.01	<.01			25
								.12	<.01/		2.0	.03	<.01	.01			15
21-II-74	8.2	2.58	92.0	71.0	21.0	84.0	3.5	.11	.01/	<.01	1.5	.02	<.01	.01			1
	8.2	2.58	93.0	72.0	21.0	84.5	3.5	.08	<.01/	<.01	2.0	.01	<.01	.01			25
25-II-74								.04	<.01/	.02	1.5	0	.01	<.01			1
								.03	.03/	.02	2.0	.10	<.01	.01			25
28-II-74	8.3	3.10	107.0	64.0	43.0	91.0	4.0	.30	.05/	0	2.0	0	<.01	<.01			1
	8.2	3.75	95.0	63.0	32.0	89.0	5.0	.17	.04/	.02	2.0	0	<.01	<.01			25
23-III-74	8.25	2.45	92.3	68.0	24.3	86.5	3.0	.18	<.03		2.0						1
	8.30	2.45	90.5	67.0	23.5	87.0	3.0	.19	.05/<.03		2.0						25
29-III-74	8.1	2.7	93.8	67.8	26.0	86.0	3.0	.06	<.03		2.5						1

four

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					(1) Yellow Bay												
DATE	pH	Si	T Hard	Ca	Mg	Alk	CO_2	NO_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
29-III 74	8.2	2.7	95.0	67.0	28.0	86.7	3.0	.29	<.03		2.4						20
8-IV-74	8.35	1.9	83.5	66.0	17.5	85.9	2.0	.04	<.03		3.0						1
	8.25	2.1	83.9	66.0	17.9	85.9	2.5	.22	<.03		3.0	.04	<.01	<.01			20
11-IV 74	8.4	2.0	92.5	64.9	27.6	86.0	3.0	.02	.28/<.03		2.8	.03	<.01	.01			1
	8.2	2.2	91.0	66.0	25.0	86.2	3.0	1.9	.03/		3.0	.09	<.01	.01			20
13-IV 74								.09	.43/<.03		3.0						1
22-IV 74	8.2	3.15	-	60.9	-	85.8	3.5	.04	<.03		3.0	.04	<.01	<.01			1
	8.1	3.0	-	64.0	-	85.5	3.0	.04	<.03		3.0	.04	<.01	<.01			25
17-V-74	8.5	3.3	90.5	69.0	21.5	89.0	3.0	0.0	<.03		5.5	0	<.01	<.01			1
	8.5	3.0	88.5	68.0	20.5	88.0	4.0	0.0	<.03		5.3	.02	<.01	<.01			25
11-VI 74	7.7	3.4	91.0	67.0	24.0	86.0	4.0	9.6	<.03		10.0	.02	<.01	<.01	0	<.01/	1
	8.2	3.0	90.5	67.3	23.2	86.5	4.0	0.0	<.03		7.0	.02	<.01	<.01	0	<.01/	25
								.04	2.6/<.03		3.0						4
27-VI 74	8.15	-	86.0	62.0	24.0	82.3	4.0	0			-	0	11	.01	0	<01/<002	1
	8.1	-	86.5	63.0	23.5	81.5	5.0				-	.02	11	.01	0	<01/<002	25

(2) Midlake Deep

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DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos/O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
29-III 74	8.1	2.1	89.8	70.0	19.8	85.8	3.0	.08	<.03		2.5	.02	<.01	.01			1
	8.3	2.35	93.2	69.0	24.2	85.5	3.5	.20	.03/		2.4	.02	<.01				40
8-IV-74	8.3	1.8	89.0	65.0	24.0	85.7	3.0	.16	<.03		3.0	0	<.01	<.01			1
	8.1	2.3	88.0	67.5	20.5	85.2	3.0	.04	<.03		3.0	.01	"	"			40
11-IV 74	8.3	1.9	88.5	68.8	19.7	86.6	2.5	.31	<.03		3.0	.02	"	"			1
	8.2	2.5	92.0	68.5	23.5	87.0	3.0	.02	.18/<.03		3.0	.09	<.01	.01			40
22-IV 74	8.2	2.6	6	61.8	-	86.0	3.0	.04	.03/<.03		3.0	.04	"	"			1
	8.1	3.0	-	64.5	-	85.0	3.0	.04	.03/<.03		3.0	.02	"	"			40
	8.15	3.2	-	60.0	-	85.0	3.0	.04	<.03		3.0	.03	"	<.01			60
17-V-74	8.7	2.8	91.0	75.0	16.0	88.0	4.0	0.0	<.03		5.2	0	"	"			1
	8.4	3.0	91.0	73.0	18.0	87.5	4.0	0.0	<.03		4.2	.02	<.01	<.01			40
6-VI-74								0.0	<.03		8.0						10
11-VI 74	8.2	3.8	91.0	67.0	24.0	85.0	3.5	4.7	<.03		10.0	.03	<.01	<.01	0	<.01/	1
	7.9	3.5	89.0	66.5	22.5	86.5	4.0				-	0	"	"	0	"	25
27-VI 74	8.1	-	88.0	67.0	21.0	83.0	4.0				-	0	.03	.01	0	<.01/<.001	1

(2) Midlake Deep

DATE	pH	Si	T Hard	Ca	Mg	Alk	CO_2	NO_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
2-VI-74								4.7	<.03		-	2.5	<.01	.02	.02	<.01/	10
7-VI-74	7.85	-	93.5	67.0	26.5	85.0	5.0				-	.01	<.01	<.01	0	<.01/<.001	40
-VII-74	8.05	-	87.0	61.0	26.0	80.5	3.0				-	.01	.03	"	0	"	1
	8.15	-	92.5	66.0	26.5	86.5	3.5				-	.01	.03	<.01	0	"	40
8-VII 74	8.0	-	80.0	57.5	22.5	78.5	3.5				-	0	<.01	"	0	"	1
	8.0	-	95.5	63.0	32.5	85.5	3.0				-	0	"	"	0	"	40
												.24	<.01	.04	0		40

						(2) Midlake Deep											
DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
31-X-73	8.0	2.3	88			88	5.0	.14	<.01		6.0						40
8-XI-73	8.15	2.1	87.0	63.5	23.5	87.0	3.7	.22	.04/<.01		6.5						1
	8.15	2.2	86.9	62.3	24.6	86.0	4.0	.09	.04/<.01		5.0						40
	8.0	2.3	87.0	63.4	23.6	87.5	4.1										80
9-XI-73	7.6	1.9	90.3	65.9	35.6	85.7											80
21-XI-73	7.4	1.8	87.7	63.9	23.8	85.5	5.0	.23	<.01		6.0	.03	<.01	<.01			1
	7.5	1.7	87.4	66.7	20.7	85.7	4.0	.31	<.01		6.0	.37	<.01	<.01			40
	7.5	1.8	87.5	66.4	21.1	85.4	7.0	.40	<.01		5.5	.09	<.01	<.01			80
7-XII 73	7.5	2.1	87.5	62.8	24.7	85.8	4.0				5.0						1
	7.5	2.1	87.5	62.8	24.7	85.8	4.5				5.0						40
	7.5	2.1	87.5	62.8	24.7	85.5	3.2				5.0						80
18-I-74	8.15	1.7	87.5	64.7	22.8	85.5	3.0	.04	.02/		3.0	.04	<.01	.01			1
	8.25	2.1	90.0	63.0	27.0	85.0	3.0	.07	.02/		3.0	0	<.01	<.01			40
4-II-74	8.35	1.5	90.5	68.0	21.5	84.5	3.0	.17	.07/		2.5	.01	<.01	.01			1
	8.35	1.8	94.5	67.5	27.0	87.5	3.0	.23	<.01/		2.5	0	<.01	.01			40

three

(2) Midlake Deep

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
15-II-74	8.20	2.28	91.0	66.0	25.0	85.5	3.0	.12	<.01/	<.01	2.5	.01	<.01	.01			1
	8.30	2.30	90.0	68.0	22.0	85.0	3.0	.12	.09/	.01	2.5	0	<.01	.01			40
21-II-74	8.1	1.99	94.0	73.0	21.0	85.5	3.5	.01	.01/	<.01	2.0	0	<.01	.01			1
	8.30	2.40	89.0	70.0	19.0	85.5	3.5	.11	<.01/	<.01	2.0	.01	<.01	.01			40
25-II-74								.03	<.01/	.05	1.5	0	<.01	<.01			1
								.05	<.01/	.03	2.0	0	<.01	.01			40
28-II-74	8.0	2.7	95.0	65.0	30.0	88.0	5.0	.21	.03/	.06	2.5	0	<.01	<.01			1
	8.2	2.5	95.0	64.0	31.0	88.0	4.0	.23	.01/	<.01	2.5	0	<.01	.01			40
7-III 74	8.0	2.95	88.0	62.0	26.0	86.0	3.0	.06	.03/ <.03	.30	2.5	0	<.01	<.01			1
								.06	.05/ <.03	.01	2.5	-					20
	8.1	3.08	88.0	62.0	26.0	87.0	2.5	.06	<.03	.01	2.5	.01	<.01	<.01			40
10-III 74	7.9	2.5	88.5	63.0	25.5	86.0	2.0	.14	.06/ <.03	<.01	2.2	.02	<.01	.01			1
	8.25	3.0	88.0	63.0	25.0	86.5	2.5	.15	<.01/ <.03	"	2.2	.02	"	"			40
21-III 74	8.1	2.64	93.5	68.5	25.0	89.5	3.0	.11	.03/ <.03	.04	2.0	.02					1
	8.3	2.7	93.5	66.0	27.5	87.0	3.0	.17	<.01/ <.03	<.01	2.0	.02					40

DATE	pH	Si	T Hard	Ca	Mg	(3) Yenne Point			T Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
						Alk	Co_2	No_3	O Phos								
21-VIII 73								.01	.03/.03		19.5						S
								.01	.01/.01		19.0						D
29-VIII 73								.02			20.0						S
								.06			19.0						D
27-IX 73								.07			14.2						1
								.11			6.0						40
08-X-73								.09			13.5						1
								.03			12.5						10
								.11			6.5						40
18-X-73		2.0	86			80.5	4.0										1
		2.1	85			89	5.5										40
9-XI-73	7.2	2.0	90.0	65.3	24.7	84.0	-	.13	.06/<.01		7.0						1
	7.3	2.2	88.9	63.9	25.0	84.7	-	.17	.54/<.01		6.0						40
15-XI 73	7.4	1.6	87.9	64.7	23.2	85.7	5.5	.11	<.01		7.0						1
	7.6	1.8	88.0	63.9	24.1	85.5	4.0	.11	.01/<.01		6.5						40

two

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DATE	pH	Si	T Hard	Ca	Mg	(3) Yenne Point			T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
						Alk	Co_2	No_3									
15-XI 73	7.7	1.9	89.3	63.0	26.3	86.0	4.0	.16	.02/<.01		6.0						75
30-I-74	8.35	1.6	88.0	65.0	23.0	84.5	-	0.0	0.0		2.0	0	<.01	<.01			1
	8.2	1.7	96.0	73.0	23.0	83.5	-	0.0	0.0		2.0	.02	"	"			40
11-II 74	8.15	2.34	89.0	66.0	23.0	86.0	-	.18	.02/	.03	2.5	.04	<.01	"			1
	8.15	2.90	89.5	63.0	26.5	84.8	-	.17	.02/	.04	2.5	.05	"	"			40
25-II 74								.07	.01/	.03	2.0	0	<.01	.01			1
								.12	.01/	<.01	2.0	0	<.01	.01			40
10-III 74	8.2	3.4	87.0	62.0	25.0	85.0	2.5	.16	.03/<.03	.08	2.2	.04	<.01	<.01			1
	8.35	3.2	88.0	63.0	25.0	86.0	2.5	.38	.05/<.03	.02	2.2	.03	"	.02			40
26-III 74	8.1	2.1	92.0	69.5	22.5	87.0	3.0	.05	<.03		2.5	.02	"	<.01			1
	8.1	2.2	96.0	72.0	24.0	86.5	3.5	.08	<.03	.08	2.5	.02	"	"			40
17-IV-74	8.27	3.2	-	65.5	-	85.5	-	.04	<.03		3.5	.10	"	"			1
	8.17	3.2	-	69.8	-	85.5	-	.07	<.03		3.1	.03	"	<.01			40
23-IV-74	8.2	2.8	-	61.0	-	87.5	3.0	.04	.03/<.03		3.0	0	.01	"			1
	7.9	3.2	-	63.0	-	86.0	3.0	.04	.03/<.03		3.0	.01	<.01	.01			40

							(3) Yenne Point		T Phos								thr
DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	O Phos	T. K.	T	Fe	Cu .	Zn .	Mn	Co/Cd	Depth
22-V-74	8.1	3.6	99.0	62.5	36.5	88.5	4.0	.06	.03/		5.0	.02	<.01	<.01			1
																	20
	8.1	3.5	90.0	63.0	27.0	88.0	4.0	0.0	<.03		5.0	.05	"	"			40
10-VI-74	8.2	3.9	87.0	65.5	21.5	86.5	4.0				-	0	"	"	0	<.01/	1
	7.9	3.0	89.0	63.0	26.0	88.0	4.0				-	0	"	"	0	"	40
17-VII 74	7.85	-	81.0	58.5	22.5	80.0	3.0				-	.01	"	.01	0	<.01/ <.001	1
	7.9	-	92.0	63.5	28.5	86.0	3.5				-	0	"	<.01	0	"	40

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(4) Skidoo Bay

ATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	one Depth
7-VIII 73								.01	<.01		20.5						S
2-VIII 73								.03	<.01		20.5						S
75 A								.02	.02/.01		20.0						D
9-VIII-73								.02			20.0						S
								.03			18.5						D
3-IX-73								.03			17.5						D
6-IX-73								.01			15.0						1
								.01			6.5						40
0-XI-73	7.7	1.9	86.0	64.5	21.5	86.5	3.5	.09	.04/<.01		7.5						1
	7.7	2.1	87.5	64.0	23.5	85.5	4.0	.29	.03/<.01		7.3						40
	7.6	2.4	87.0	66.0	21.0	85.9	4.5	.33	.02/<.01		6.3						70
2-XI-73	7.5	1.8	88.0	65.5	22.5	85.8	3.0	.12	<.01		6.0	.03	<.01	.01			1
	7.5	1.8	86.5	65.0	21.5	86.0	3.9	.29	<.01		6.0	.04	"	<.01			40
	7.45	2.2	89.5	65.2	24.3	85.2	4.0	.41	<.01		5.5	.03	"	"			80
24-I-74	8.3	2.1	86.5	62.0	24.5	85.0	2.5	.03	.02/		3.0	0	"	.01			1

9(4) Skidoo Bay

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
24-I-74	8.2	2.1	87.5	63.5	24.0	85.5	3.0	.08	-		3.0	0	<.01	<.01			40
8-II-74	8.2	6.3	90.0	65.0	25.0	85.5	3.0	.08	.01/		3.0	.04	"	"			1
	8.25	6.3	89.5	70.0	19.5	85.0	3.0	.11	.01/		3.0	0	"	"			40
21-II 74	8.2	2.98	91.5	68.0	23.5	84.5	4.0	.08	<.01/	<.01	2.5	0	<.01	<.01			1
	8.3	2.28	87.0	65.5	21.5	85.5	4.0	.09	<.01/	<.01	2.5	.02	"	"			40
7-III-74	8.2	3.32	87.0	62.5	24.5	86.0	3.0	.03	<.03	.01	2.5	.01	<.01	<.01			1
	8.1	4.13	87.0	62.0	25.0	86.0	3.0	.11	<.03	.01	2.5	0	"	"			40
	8.2	4.34	8 .5	62.0	24.5	86.0	2.5	.06	<.03	.01	2.5	0	"	"			80
22-III 74	8.1	2.65	94.0	72.0	22.0	88.5	4.0	.26	.05/ <.03	<.01	2.5	.02	"	"			1
	8.2	2.9	97.0	76.0	21.0	87.5	3.5	.10	.06/ <.03	"	2.5	.01	"	"			40
11-IV-74	8.3	.17	89.8	69.0	20.8	86.5	3.5	.11	.05/ <.03		3.0	.02	"	"			1
	8.2	2.4	91.0	70.0	21.0	85.5	4.0	.13	<.03		3.0	.05	<.01	.01			40
11-V-74	8.3	3.0	-	66.5	-	86.3	3.0	0.0	<.03		3.0	0	"	<.01			1
	8.3	2.75	-	66.0	-	85.5	3.0	0.0	.04/ <.03		3.0	.02	"	"			40
29-V-74	8.2	3.15	90.5	67.0	23.5	85.5	3.0	0.0	<.03		8.0	.02	"	"	0		1

						(4) Skidoo Bay											three
DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
12-VI-74								0	<.03		-	.03	<.01	.01	0	.01/	1
13-VI-74	8.2	-	90.5	63.0	27.5	85.5	4.0				-	0	<.01	<.01	0	<.01/	1
	8.5	-	90.5	65.0	25.5	85.5	4.0				-	0	<.01	"	0	"	40
27-VI-74	8.15	-	89.0	66.0	23.0	81.0	4.0				-	.01	"	.01	.02	<.01/ <.001	1
	8.05	-	90.5	73.0	17.5	84.5	4.5				-	0	"	"	.01	"	40
18-VII-74	8.1	-	85.0	60.0	25.0	80.0	3.5				-	0	"	<.01	0	"	1
	8.1	-	91.5	62.5	29.0	87.5	3.5				-	0	"	.01	0	"	40
								.14	<.03		-	.05	"	"	0	<.01/	5
								.04	"		-	2.7	.02	.07	.07	"	10
								.13	"		-	.07	<.01	<.01	0	"	20

							(5) Polson Bay		T Phos								one
DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
22-VIII 73								.01	.01/.01		21.0						S
26-IX-73								.07			14.5						1
								.03			14.2						5
10-XI-73	7.7	2.1	90.5	64.5	26.0	84.5	4.0	.07	.05/<.01		4.0						1
	7.7	2.0	88.0	63.0	25.0	85.9	4.0	.11	.32/<.01		4.0						5
4-XII 73	7.5	2.2	87.5	62.5	25.0	85.3	4.0				3.5						1
	7.5	2.0	88.0	63.0	25.0	85.5	4.0				3.5						5
24-I-74	8.2	1.9	88.0	63.0	25.0	86.0	3.0	.01	.02/		2.5	0	<.01	.01			1
	8.3	1.9	90.0	66.5	23.5	86.0	3.0	.09	.01/		2.5	0	"	"			5
8-II-74	8.25	5.52	90.0	65.0	25.0	84.5	3.5	.13	.01/		2.5	0	"	"			1
	8.25	5.70	89.0	65.0	24.0	85.0	3.5	.08	.01/		2.5	0	<.01	<.01			4
21-II 74	8.15	2.28	92.5	73.8	18.7	84.5	3.5	.08	<.01/	.01	2.0	.02	<.01	.01			1
	8.35	2.33	93.3	72.0	21.3	85.0	3.5	.01	.01/	"	2.0	0	"	"			5
7-III-74	8.3	2.65	87.0	62.0	25.0	86.0	3.5	.13	<.03	.20	2.0	"	<.01	<.01			1
	8.2	2.53	87.0	62.5	24.5	88.0	3.0	.36	.03/<.01	.25	2.0	0	"	"			5

(5) Polson Bay

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	two Depth
12-III 74	8.1	2.9	92.5	74.0	18.5	87.0	3.0	.20	.04/<.03	.28	2.5	.01	<.01	<.01			1
	8.2	3.05	96.5	75.5	21.0	86.5	3.5	.20	.05/<.03	.27	2.5	.01	"	"			4
11-IV-74	8.15	1.6	90.0	67.9	22.1	85.5	3.0	.13	.06/<.03		3.0	.02	"	"			1
	8.1	2.1	86.5	66.9	19.6	85.1	3.0	0.0	<.03		3.0	.03	"	"			3
11-V-74	8.1	2.8	-	68.0	-	86.5	3.0	0.0	<.03		3.0	0	"	"			1
	8.3	2.95	-	67.5	-	86.0	3.0	0.0	<.03		3.0	0	"	"			5
29-V-74	8.2	3.6	89.0	65.0	24.0	85.0	3.5	.04	<.03		8.0	1.3	<.01	<.01	.01	<.01/	1
	8.2	3.4	94.0	65.0	29.0	85.0	3.5	0.0	<.03		6.0	.01	"	"	0	"	5
13-VI-74	8.10	-	89.0	61.5	27.5	85.5	4.0				-	"	"	<.01	"	"	1
	8.05	-	89.5	61.5	28.0	86.5	3.5				-	0	"	"	0	"	5
27-VI-74	7.9	-	86.5	64.0	22.5	81.0	5.0				-	"	<.01	<.01	"	<.01/ < .001	1
	8.25	-	91.0	67.0	24.0	79.0	4.5				-	0	"	.01	0	"	5
18-VII 74	8.1	-	83.0	57.5	25.5	76.0	3.5				-	0	"	.01	"	"	1
	8.0	-	82.0	59.0	23.0	76.0	3.0				-	.01	.03	<.01	0	"	5
12-VI-74												.01	<.01	.03	0	<.01/	3

(6) Below Polson Bridge

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co$_2$	No$_3$	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
26-IX-73								.11			14.1						1
								.04			-						3
10-XI-73	7.5	2.3	88.0	64.0	24.0	85.3	3.4	.13	.04/<.01		4.0						1
	7.6	2.3	36.8	62.8	24.0	85.3	3.5	.25	.09/<.01		4.0						3
16-XII 73	8.4	1.4	88.0	63.0	25.0	85.5	2.7	.01	.03/<.01		3.0	.04	<.01	<.01			1
	7.9	1.8	88.0	52.5	25.5	85.5	3.2	.05	.02/<.01		3.0	.02	"	.01			5
14-I-74	8.1	2.0	90.0	63.5	25.5	87.5	3.0	.05	<.01/ .03		-	0	"	"			1
	8.1	1.7	88.5	64.0	24.5	86.5	3.0	.03	.01/<.01		-	0	"	"			3
24-I-74	8.35	1.8	87.0	64.5	22.5	86.0	2.5	.0	<.01		2.5	"	<.01	.01			1
	8.4	1.9	91.0	62.0	29.0	84.5	2.5	.04	.02/		2.5	0	"	"			3
8-II-74	8.3	6.30	85.9	65.0	20.9	84.5	3.5	.12	.01/		2.5	"	"	"			1
	8.2	6.45	93.0	64.9	28.1	84.5	3.5	.07	<.01/		2.5	.03	<.01	.01			3
21-II-74	8.25	2.80	91.2	68.0	23.0	85.5	4.0	.01	.01/	<.01	2.0	.02	"	"			1
	8.35	2.90	89.0	61.0	28.0	84.5	4.0	.02	<.01/	"	2.0	.02	"	"			3
7-III-74	8.2	3.08	88.0	63.0	25.0	90.0	3.0	.08	.03/<.03	.02	2.0	.02	<.01	<.01			1

two

(6) Below Polson Bridge

ATE	pH	Si	T Hard	Ca	Mg	Alk	CO_2	NO_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
-III-74	8.1	2.48	88.0	62.0	26.0	86.0	3.0	.14	.05/<.03	.18	2.0	0	.01	.01			3
8-III 74								.18	<.03	<.01	2.0	.01					1
2-III 74	8.0	3.15	97.5	66.3	31.2	87.0	3.5	.18	.03/<.03	<.01	2.5	.24	"	.01			1
	8.1	2.85	98.0	64.5	33.5	85.0	3.5	.15	.04/<.03	.67	2.5	<.01	<.01	.01			3
								.13	<.03	.35	2.0	.03					3
1-IV-74	8.3	2.3	88.5	68.0	20.5	86.0	3.0	.22	<.03		3.0	.02	<.01	<.01			?
-V-74	8.3	2.75	-	70.0	-	86.0	3.0	0.0	<.03		4.0	0	"	"			2
-V-74	8.15	2.75	-	62.0	-	85.7	4.5	.67	<.03		4.0	.01	"	"			2
1-V-74	8.25	2.55	-	66.5	-	86.5	3.0	0.0	<.03		3.0	0	"	"			2
9-V-74	8.2	3.2	91.5	66.0	25.5	87.0	3.5	.05	.03/<.01		6.0	.03	"	"	0	<.01/	2
3-VI-74	8.2	-	88.0	61.5	26.5	86.0	4.0				-	0	<.01	<.01	0	"	2
7-VI-74	8.1	-	86.5	63.0	23.5	81.0	3.5				-	.02	"	.01	"	<.01/ <.001	2
8-VI-74	8.0	-	85.5	66.0	19.5	82.0	4.0				-	.01	"	.04	0	"	1
8-VII 74	8.1	-	83.0	64.0	19.0	78.5	3.0				-	0	.07	.01	0	"	2

81<

(7) Bigarm Bay

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
09-VIII 73								.01	.03/.01		21.5						S
								.01	.01/<.01		19.0						D
04-IX-73								.02			15.5						D
26-IX-73								.06			14.2						1
								.13			6.5						35
9-XI-73	7.5	1.9	86.9	63.5	23.4	85.7	-	.09	.08/<.01		7.0						1
	7.5	2.1	89.4	64.0	25.4	85.5	-	.06	.05/<.01		7.0						27
30-XI-73	7.52	1.9	88.2	63.0	25.2	86.6	3.0	0	<.01		5.5	.05	<.01	<.01			1
	7.55	2.0	88.5	62.5	26.0	86.3	3.0	0	<.01		5.5	.06	"	"			30
18-XII 73	8.3	1.5	89.5	63.0	26.5	-	4.0	.05	.02/		4.8	0	"	"			1
	8.4	1.8	89.9	62.5	27.4	-	4.0	.01	.03/		4.6	"	<.01	.01			35
24-I-74	8.15	1.7	89.0	66.0	23.0	84.5	3.0	.10	<.01/		2.5	0	"	<.01			1
	8.25	1.9	86.5	63.5	23.0	84.5	3.0	.08	.01/		2.5	"	"	.01			40
15-II-74	8.2	2.15	89.0	67.0	22.0	85.0	3.0	.08	<.01/	<.01	2.0	.01	<.01	"			1
	8.3	2.55	90.0	68.5	21.5	85.0	3.0	.08	.03/	"	2.0	.04	"	"			35

two

(7) Bigarm Bay

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
7-III-74	8.1	3.08	87.0	63.0	24.0	87.0	2.5	.06	.03/<.03	.02	2.5	0	<.01	<.01			1
	8.1	2.50	87.0	62.0	25.0	87.0	3.0	.12	.06/<.03	<.01	2.5	"	"	"			25
29-III 74	8.2	2.45	89.0	70.0	19.0	85.8	3.0	.28	.03/		3.2	0	.01	<.01			1
	8.25	2.5	88.8	75.0	13.8	85.8	3.0	.07	<.03		3.2	"	<.01	"			25
15-IV-74	8.3	2.9	95.8	66.8	29.0	86.5	-	0.0	<.03		3.0	.06	"	"			1
	8.25	3.0	90.2	66.0	24.2	87.0	-	0.0	<.03		3.0	.04	"	.01			30
29-V-74	8.35	3.1	90.0	67.0	23.0	87.0	3.0	0.0	<.03		8.0	0	<.01	<.01	0	.01/	1
	8.1	2.8	92.0	68.0	24.0	86.5	4.0	0.0	<.03		5.0	.02	"	"	.01	"	35
13-VI-74	8.1	-	90.5	64.0	26.5	85.5	3.5				-	0	"	"	0	"	1
	7.8	-	89.5	64.5	25.0	87.0	4.0				-	"	<.01	<.01	"	"	35
18-VII 74	8.15	-	81.0	59.0	22.0	80.0	2.5				-	0	"	.01	0	<.01/ <.001	1
	8.0	-	89.0	63.5	25.5	86.0	3.5				-	.01	"	<.01	0	"	35

Flathead River Mouth

ATE	pH	Si	T Hard.	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
08-VIII 73								.01	.01/.01		21.0						S
								.01	<.01		20.0						D
21-VIII 73								.02	.01/.01		20.0						S
								.01	.03/.01		18.5						D
27-IX-73								.13			11.0						1
								.16			11.0						8
18-X-73		2.5	86.7			88.7	5.0	.56	0		7.0						1
		2.7	88.0			88.0	4.0	.46	0		7.0						9
9-XI-73	7.5	2.3	82.5	62.9	20.4	82.3	-	.33	.02/<.01		2.0						1
	7.5	2.6	84.5	63.9	21.4	82.5	-	.58	.14/<.01		2.5						8
26-XI-73	7.55	2.0	97.0	69.7	27.3	87.8	5.0	.51	<.01		1.0	.05	<.01	<.01			1
	7.55	2.2	95.7	67.2	28.5	88.0	5.0				1.0	.04	"	"			5
30-I-74	8.2	2.1	93.5	66.5	27.0	89.5	-	-	-		1.5	.01	"	.01			1
	8.15	2.3	93.0	69.0	24.0	88.8	-	.20	.01/		1.5	.10	<.01	"			7
22-V-74	8.2	5.7	101.0	70.0	31.0	91.0	4.0	.08	.03		4.0	.19	"	<.01			1

two

Flathead River Mouth

DATE	pH	Si	T Hard	Ca	Mg	ALK	CO_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
22-V-74	8.2	5.5	100.0	68.0	32.0	90.5	4.0	.09	<.03		4.0	.11	<.01	<.01			5
25-V-74	8.1	5.1	93.0	66.0	27.0	89.0	4.0				7.5						1
30-V-74								.27	.25/		8.0	.03	.01	"	.01	<.01/	1
								.24	.09/		8.0	.09	<.01	"	0	"	25
10-VI-74	7.8	5.0	85.0	60.5	24.5	76.0	3.5	3.4	.12/		8.0	.04	"	<.01	.01	"	1
	7.9	5.4	81.0	58.0	23.0	76.5	3.5	11.	-		8.0	.21	"	"	"	"	8
	8.25	5.1	95.0	65.0	30.0	89.0	3.5				7.5						5
26-VI-74	8.0	-	70.0	51.5	18.5	65.0	3.5				-						1
17-VII-74	8.1	-	78.0	54.0	24.0	71.5	3.0				-	0	<.01	<.01	0	<.01/ <.001	1
	7.8	-	77.0	55.0	22.0	71.5	3.0				-	0		<.01	0	<.01/ <.001	8

(9) Bigfork Bay

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
08-VIII 73								.01	.04/.01		20.0						S
21-VIII 73								.02	.02/.01		19.5						S
30-VIII 73								.03			20.0						S
27-IX-73								.07			14.6						1
								.03			14.0						3
18-X-73		2.8	88.0			91	3.5	.11	0		11.0						1
								.17	0		11.0						3
9-XI-73	7.5	2.1	88.2	65.0	23.8	84.6	-	.18	.03/<.01		5.0						1
	7.5	2.3	86.0	63.9	23.9	86.0	-	.19	.04/<.01		4.0						3
26-XI-73	7.6	2.2	90.4	65.0	25.4	87.7	5.0	.12	<01		2.0	.03	< .01	< .01			1
	7.6	2.4	92.9	67.0	25.9	89.7	5.0	.22	.01		2.0	.04	"	"			3
30-I-74	8.2	2.1	88.0	63.0	25.0	88.0	-	.02	0.0/		1.5	.01	"	.01			1
11-II-74	8.2	4.3	92.0	70.0	22.0	90.5	-	.15	.03/	.02	2.0	.06	< .01	"			1
	8.15	5.25	99.0	75.0	24.0	91.5	-	.13	.01/	.02	2.0	.08	"	"			3
10-III 74	8.2	5.9	96.0	68.0	28.0	97.0	3.5	.20	.05/.03	.09	3.0	.03	"	<.01			1

two

(9) Bigfork Bay

DATE	pH	[illegible]	T Hard	Ca	Mg	Alk	CO_2	NO_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
26-III 74	8.3	3.8	104.0	77.5	26.5	98.0	4.0	.05	.04/		2.5	.03	<.01	.02			1
17-IV-74	8.1	6.4	106.0	83.5	-	97.5	-	.13	.21/ <.03		3.5 3.0	.04	"	<.01			1
23-IV-74	8.1	6.7	-	68.5	-	98.3	4.0	.13	.03/		3.0	.02	"	"			1
22-V-74	8.1	6.2	99.5	77.0	22.5	90.0	5.0	0.0	.03/ <.03		5.0	.01	<.01	"			1
10-VI-74	7.8	5.4	87.0	64.0	23.0	78.0	3.5	13.	<.03		10.0	.03	"	<.01	0	<.01/	2
17-VII 74	8.1	-	75.0	56.5	18.5	72.5	3.2	0	.04/ <.03		-	.01	"	"	0	<.01/ <.001	2

DATE	pH	Si	T Hard	Ca	Mg	(10) Holt Bridge Alk	Co$_2$	No$_3$	T Phos / O Phos	T. K.	T	Fe	Cu.	Zn.	Mn	Co/Cd	Depth
30-VIII 73								.08			13.0						S
04-IX-73								.03			14.5						S
								.02			-						D
15-XII 73	8.2	2.0	98	67.7	30.3	93.7	3.0	.06	.01/<.01		2.0	0	.01	.01			1
	8.1	2.2	98	68.0	30.0	94.8	3.0	.03	.01/<.01		2.0	.02	<.01	<.01			10
15-I-74	8.2	2.3	85.5	59.0	26.5	89.7	3.5	.21	/.01		3.0	.03	"	"			1
	8.2	2.5	83.5	58.8	24.7	81.0	4.0	.20	/.01		3.0	0	"	"			5
25-I-74								.27	0.0/		-						1
								.60	.01/		-						10
29-I-74	8.35	2.8	91.5	66.0	25.5	88.8	4.0	.57	.01/		2.0	0	<.01	.01			1
	8.0	2.9	91.5	67.0	24.5	88.5	4.5	.22	.01/		2.0	.02	"	"			5
30-I-74								.23	0.0/		1.5	0	"	"			1
								.34	.01/		1.5	"	<.01	<.01			5
5-II-74	8.15	2.4	97.0	68.0	29.0	92.0	4.0	.52	.01/		2.0						1
	8.2	2.6	95.0	67.0	28.0	92.0	4.0	.52	.01/		2.0						5

two

(10') Wolt Bridge

DATE	[illegible]	[illegible]	[illegible] Hard		Mg	Alk	CO_2	NO_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
25-II-74								.28	.01/	.04	1.0	0	<.01	.01			1
								.27	.01/	.02	1.0	"	"	"			6
3-III-74	8.35	3.95	87.0	70.0	17.0	85.0	3.0	0.0	.02/	.06	3.0	0	"	<.01			1
	8.25	4.05	85.0	70.0	15.0	85.0	3.0	.40	.02/	.02	3.0	"	< .01	"			5
6-III 74	8.2	3.45	85.5	61.0	24.5	86.0	3.0	.30	.04/ <.03	< .01	2.2	.04	"	"			1
	7.8	3.3	85.0	61.0	24.0	85.0	3.0	.30	.06/ <.03		2.2	.01	"	< .01			5
3-IV-74	8.1	3.1	93.5	66.0	27.5	84.5	-	.22	<.03		-	"	.01	.01			1
	8.25	3.4	97.0	79.5	17.5	97.0	-	.27	.03/ <.03		-	0	<.01	"			5
24-IV-74	8.0	5.4	-	56.0	-	84.5	3.0	.18	.03/		3.0						1
	8.0	5.3	-	56.5	-	84.5	3.0	.13	.03/		3.0						5
29-IV-74	7.85	6.5	-	72.0	-	82.5	5.0	.20	.05/		5.0	.02	.01	<.01			1
3-V-74	8.15	5.2	-	62.0	-	82.5	4.0	2.2	.03/		5.0	.01	<.01	"			1
	8.15	5.8	-	65.3	-	82.5	4.0	.91	<.03		5.0	0	"	"			5
16-V-74	8.2	5.3	-	64.0	-	86.9	5.0	.10	.10/ <.03		3.0						1
	8.2	5.5	-	62.0	-	86.5	5.0	.09	.03/		3.0						5

(10) Holt Bridge

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	thr Depth
22-V-74								.10	<.03		9.0						1
								.10	<.03		9.0						3
3-VI-74	8.2	4.7	78.0	58.0	20.0	78.0	3.0	.31	.11/		8.0	.02	<.01	<.01	0	<.01/	1
	8.1	5.0	79.0	58.0	21.0	77.0	3.0	.30	.03/ <.03		8.0	.05	<.01	<.01	0	<.01/	5
7-VI-74	7.9	4.1	81.0	57.5	23.5	77.0	3.5	.31	.16/		8.0	.03	"	"	"	"	1
	7.8	5.2	81.0	57.0	24.0	77.0	4.0	.26	.16/		8.0	"	"	"	"	"	5
19-VI-74								.27	.54/.04								1
21-VI-74	7.8	-	65.0	41.0	24.0	60.0	2.5				-	0	.04	<.01	0	"	1
26-VI-74	8.0	-	75.0	52.0	23.0	66.0	3.0				-						1
27-VI-74								.20	/.03			.02	<.01	<.01	0	<.01/ <.001	1
	7.75	-	75.5	59.0	16.5	67.5	4.0	.16	-		-	.02	<.01	.01	0	<.01/ <.001	5
16-VII-74	8.15	-	77.0	57.0	20.0	74.5	3.0	.13	<.03		-	0	"	"	"	"	1
	7.9	-	76.0	56.0	20.0	74.0	4.0	.13	<.03		-	.01	"	.01	0	"	5

(11) Painted Rocks

DATE	pH	O_2	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	one Depth
26-IX-73								.03			14.2						1
								.17			5.5						40
08-X-73								.07			13.5						1
								.02			13.0						10
								.09			6.5						40
31-X-73	8.15	1.9	92.0			87.5	3.7	.0	<.01		6.0						1
	8.1	1.8	91.0			86.8	3.7	.01	<.01		9.5						40
9-XI-73	7.6	1.9	89.7	65.7	24.0	85.3	-	.11	.07/ <.01		7.0						1
	7.6	2.3	90.9	65.0	35.9	84.8	-	.25	.10/.05		5.0						40
20-XI-73	7.3	2.1	86.2	63.0	23.2	85.7	3.0	.24	<.01		6.0	.06	<.01	<.01			1
	7.3	2.0	87.4	63.9	24.3	85.7	4.0	.34	<.01		5.5	.03	"	"			40
6-XII 73	7.6	1.9	87.0	62.0	25.0	85.0	3.0				5.0						1
	7.6	1.9	87.0	62.0	25.0	84.5	3.0				5.0						40
	7.6	1.9	87.0	62.0	25.0	84.5	3.0				5.0						80
11-II 74	8.3	2.28	90.5	72.0	18.5	84.7	-	.08	.02/	.02	2.0	.04	<.01	.01			1

(11) Painted Rocks

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	[illegible]	Zn.	Mn	Co/Cd	Depth
11-II 74	8.3	2.70	88.0	73.0	15.0	84.5	-	.09	.01/	.02	2.0	.22	<.01	.01			40
7-III-74	8.2	3.25	87.0	63.0	24.0	88.0	3.0	.09	<.03	.01	2.5	0	"	<.01			1
								.18	.03/ <.03		2.5						20
	8.25	3.18	88.0	61.5	26.5	87.0	3.25	.13	<.03	<.01	2.5	0	<.01	<.01			40
10-III 74	8.15	2.8	88.0	63.0	25.0	88.0	2.0	.13	.04/ <.03	.01	2.4	.01	"	"			1
	8.15	2.74	88.0	63.0	25.0	87.0	2.5	1.1	.06/ <.03	.02	2.4	.02	"	.01			40
29-III 74	8.2	1.95	93.0	69.0	24.0	86.0	3.0	.06	.03/		2.5	.07	<.01	<.01			1
	8.1	2.45	90.8	65.0	25.8	86.3	3.0	.04	<.03		2.5	.01	"	"			40
15-IV-74	8.1	3.2	89.0	69.5	19.5	86.4	-	0.0	<.03		3.0	.01	"	"			1
	8.3	3.0	90.5	74.5	16.0	85.9	-	0.0	<.03		3.0	.04	<.01	<.01			40
22-V-74	7.9	3.9	88.0	68.0	20.0	85.0	3.0	0.0	< .03		5.0	0	"	"			1
	8.1	3.2	91.0	64.5	26.5	86.0	4.0	0.0	<.03		5.0	.03	"	"			40
[illegible] 74	8.2	3.9	87.0	63.5	23.5	85.0	3.0	8.0	<.03		10.0	-	<.01	<.01	0	<.01/	1
	8.15	3.2	91.0	63.0	28.0	86.0	2.5	[illegible]	< .03		6.0	.04	"	"	0	"	40
[illegible]	[illegible]	-	[illegible]	[illegible]	[illegible]	78.5	[illegible]	0	.03/ [illegible]		-	0	"	"	0	[illegible] [illegible]	1

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DATE	pH	Si	T Hard	Ca	Mg	(12) Swan River Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	one Depth
04-IX-73								.04			17.0						8
01-XI-73	7.8	3.3	90.0			92.7	4.3	.05	<.01		10.0						1
	7.5	3.3	94.0			95.0	5.5	.06	<.01		9.0						4
15-XII-73	8.0	2.6	97.0	66.5	30.5	92.5	3.0	.02	.01/		2.5	0	.01	<.01			1
15-I-74	8.1	3.1	97.0	70.9	26.1	94.5	4.0	.12	/.01		1.0	.02	<.01	"			1
25-I-74								.03	0.0/		-						1
29-I-74	8.05	3.5	91.0	67.5	20.5	89.0	4.0	.38	.01/		2.0	0	<.01	.01			1
30-I-74								.33	<.01/		1.0	.01	"	"			1
5-II-74	7.85	3.3	93.5	69.0	24.5	91.0	3.5	.57	<.01/		2.0	0	"	"			1
25-II-74								.08	<.01/	.06	1.5	0	<.01	.01			1
3-III-74	8.2	6.65	96.0	67.0	29.0	97.0	3.0	.39	.05/	.07	2.0	0	"	<.01			1
6-III-74	8.25	6.35	97.5	68.0	29.5	103.0	4.0	.17	.08/.03	<.01	1.5	.04	"	"			1
21-III-74								.24	<.03/ .03	.08	2.0	.03					1
11-IV-74	8.25	5.3	97.0	79.5	17.5	97.0	-	.09	<.03		-	.02	.01	<.01			
24-IV-74	8.3	6.4	-	64.5	-	98.0	3.3	.08	.03/		3.0	4.0					1

tw

(12) Swan River

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
29-IV-74	8.1	8.1	-	79.8	-	97.0	5.0	0.0	<.03		6.0	.02	<.01	<.01			1
3-V-74	8.0	7.0	-	65.5	-	65.5	4.5	2.8	.07/ <.03		3.0	0	"	"			1
16-V-74	6.6	8.15	-	64.5	-	90.5	5.0	0.0	<.03		3.0						1
30-V-74								.07	.03		8.0	.03	<.01	<.01	.01	<.01/	1
								.04	<.03		8.0	.04	"	"	.01	"	3
3-VI-74	8.2	6.4	88.0	62.0	26.0	87.0	3.0	-	-		8.0	.17	"	"	0	"	1
7-VI-74	7.9	6.5	87.0	64.0	23.0	85.5	3.5	0.0	<.03		8.0	.05	<.01	<.01	"	"	1
	8.1	6.1	87.0	61.0	26.0	85.0	3.5	.98	<.03		8.0	.05	"	"	"	"	3
21-VI-74	7.7	-	58.0	36.0	22.0	56.0	3.0				-	0	.04	"	0	"	1
26-VI-74	8.1	-	79.5	58.0	21.5	68.0	4.5	.05	/<.03		-	.03	<.01	.01	.01	<.01/ <.001	1
16-VII-74	7.7	-	72.5	54.0	18.5	70.0	3.5	0	<.03			0	"	"	0	"	1
19-VI-74								.09	.36/ <.03								1

one

(13) North End

DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	T Phos / O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
27-IX-73								.08			14.2						1
								.08			7.5						25
18-X-73		1.9	88.0			86.0	3.3				-						1
		2.1	84.0			85.5	4.5				-						23
15-XI-73	7.8	1.7	85.4	65.9	19.5	84.9	6.0	.09	.01/ <.01		6.0						1
	7.8	1.8	85.7	65.0	20.7	84.5	5.0	.13	<.01		5.5						25
26-XI-73	7.65	2.0	88.3	63.1	25.2	85.0	4.0	.22	<.01		5.5	.02	<.01	<.01			1
	7.65	2.1	89.7	64.1	25.6	84.6	5.0	.22	<.01		5.5	"	"	"			30
11-II 74	8.25	2.40	89.0	65.0	24.0	84.0	-	.15	.01/	.02	2.0	.04	"	.01			1
	8.35	3.05	91.5	69.0	22.5	84.0	-	.02	.01/	.04	2.0	.04	<.01	"			30
10-III 74	8.2	3.0	88.0	62.0	26.0	85.5	2.0	.15	.06/ <.03	<.01	2.2	.01	"	<.01			1
	8.25	3.25	89.0	63.0	26.0	85.0	2.5	.16	.07/ <03		2.2	.03	"	.01			25
26-III 74	8.15	2.45	94.0	74.5	19.5	87.0	3.5	.12	.06/ <.03	<.01	2.5	.01	<.01	"			1
	8.2	33.5	90.5	68.0	22.5	86.0	3.5	.35	.18/ .19	.05	2.5	.01	"	<.01			30
17-IV-74	8.25	4.3	-	71.4	-	85.6	-	.11	<.03		3.0	.03	"	"			1

95<

					(13) North End				T Phos								twc
DATE	pH	Si	T Hard	Ca	Mg	Alk	Co_2	No_3	O Phos	T. K.	T	Fe	Cu	Zn	Mn	Co/Cd	Depth
17-IV-74	8.1	3.5	-	69.5		85.8	-	.04	<.03		3.0	.04	<.01	<.01			20
23-IV-74	8.3	4.0	-	63.5	-	85.0	3.0	.09	.03/		3.0	.03	"	"			1
	8.0	4.3	-	66.0	-	84.0	3.0	.18	.03/		3.0	.01	"	"			30
22-V-74	8.2	4.5	88.0	67.0	21.0	85.0	3.5	.04	<.03		5.0	.02	"	"			1
	8.2	4.6	90.0	76.0	14.0	86.0	4.0	.04	<.03		5.0	.03	<.01	<.01			30
10-VI-74	8.15	4.1	85.0	59.5	25.5	84.0	3.5	.40	<.03		10.0	.05	"	"	0	<.01/	1
	8.0	4.1	83.5	61.0	22.5	81.0	3.5	.12	<.03		6.0						30
17-VII 74	7.8	-	80.0	57.5	22.5	78.0	3.0	.05	<.03		-	.01	<.01	<.01	0	<.01/ <.001	1
	8.1	-	90.0	64.0	26.0	86.0	3.0	.06	"		-	0		.01	0	"	30
11-VI-74								.13	<.03			.08	<.01	.02	0	<.01/	1